VANCOUVER ISLAND
ROOSEVELT ELK/
INTENSIVE FORESTRY
INTERACTIONS

PROGRESS REPORT
1981-1984

INTEGRATED WILDLIFE INTENSIVE FORESTRY RESEARCH

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A cooperative project between the Ministries of Environment and Forests

VANCOUVER ISLAND ROOSEVELT ELK/INTENSIVE FORESTRY INTERACTIONS

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1981 - 1984

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and
D. Becker

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SUMMARY

A Roosevelt elk (*Cervus elaphus roosevelti*) population was studied near Campbell River, B.C., from April 1981 through June 1984. Thirty-one elk were radio-collared, including 24 adult cows, 2 yearling bulls, 3 adult bulls, and 2 calves. Both migratory and non-migratory movement patterns were exhibited. Annual home range sizes of migratory elk were approximately six times larger than those of non-migratory elk. Densities on annual ranges varied from 0.6 to 3.0 elk per square kilometer. Densities on seasonal ranges (winter and summer) varied from 1.6 to 6.5 elk per square kilometer. Summer calf:cow ratios in two migratory herds averaged 46 calves per 100 cows. Spring calf:cow ratios from these two herds averaged 36 calves per 100 cows and were negatively correlated with winter severity ($p<.02$)..

Elk diets varied by season: spring diets were dominated by shrubs, ferns, and graminoids; summer diets contained high proportions of shrubs and half shrubs; fall diets showed a shift to ferns and conifers; and winter diets were dominated by graminoids, conifers, and ferns. Use-availability comparisons indicated that *Blechnum spicant*, grasses, *Linnaea borealis*, *Tsuga heterophylla*, and sedges were the preferred plant taxa during both the 1983 and 1984 winters. Multiple regression analyses and Spearman rank correlations indicated no significant relationships between four diet species variables (tannin content, percent availability, percent crude protein, and percent dry matter digestibility) and percent use in the winter diets ($p>.10$).

During two mild winters (1983 and 1984), elk displayed a preference for bogs, deciduous stands, and 20- to 60-year-old second growth and avoided 0- to 20-year-old second-growth and 20- to 40-year-old spaced second-growth stands. A multiple regression model incorporating four habitat variables (mean percent cover of sedges, mean percent cover of grasses,

canopy closure, and mean percent cover (below 2 m) of Tsuga heterophylla) was significant ($p<.025$) and explained 95% of the variation in stand type preference. Within stand types, elk selected wetter ecosystem associations (moss-Mahonia and Carex-Myrica-Spiraea) and avoided the drier ecosystem associations (Gaultheria and Rhacomitrium-lichen).

Home range sizes decreased as the proportion of bogs within the home range increased, suggesting a relationship between carrying capacity of mild winter range and abundance of this habitat component.

Elk habitat use during summer also indicated a preference for bogs and deciduous stands. There was high use of old-growth (38%) and 0- to 20-year-old second-growth stands (34%) on summer range, though these stand types were used only in proportion to availability.

The majority of calving sites occurred on summer range, and seven of nine occurred in second growth. Minimal slope and adequate security cover appeared to be the primary factors affecting calving site selection.

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1 INTRODUCTION AND OBJECTIVES

The management of elk (Cervus elaphus roosevelti) on Vancouver Island depends upon the protection and provision of important elk habitats through integrated forest management. Thus, knowledge about elk habitat needs and the impacts of intensive forest management practices on these needs is basic for effective integration of both resources. The present study was initiated in 1980 to provide this knowledge. The project is a part of the Integrated Wildlife-Intensive Forestry Research (IWIFR) Program, a five-year co-operative effort between the Ministry of Environment and the Ministry of Forests.

The general objective of the elk research project is to collect information on elk habitat use in immature forests, and to use this information in formulating management recommendations. Specific objectives are to examine the effects of silvicultural activities on elk:

i) seasonal habitat use;
ii) food habits;
iii) migratory habits;
iv) animal condition; and
v) population status.

In addition to these objectives, the research project addressed the following sets of questions concerning elk:

a) habitat use:
   i) What are the important physical characteristics of thermal cover?
   ii) Can second-growth stands under 80 years of age serve as adequate thermal cover?
   iii) What are the physical characteristics and requirements of security cover?
   iv) What are calving habitat requirements?
   v) What is the optimal forage to cover ratio on summer and winter ranges?

vi) Which stand and ecosystem types are most important on a seasonal basis? What activities are they used for?

vii) Which forage species are preferred on a seasonal basis?

viii) What is the influence of spacing debris on elk mobility and habitat use?

ix) What is the influence of silvicultural treatments on physical environmental parameters such as snow depth, windspeed, and air temperature?

b) population:

i) What is the influence of winter severity on population growth, and how is this modified by silvicultural treatments?

ii) What are the factors most influencing animal condition, and how are these modified by silvicultural treatments?

iii) What is the impact of predation on elk populations, and how is this modified by silvicultural treatments?

This report presents analyses and ecological interpretations of all data collected to date (1981-1984).

2 STUDY AREA

The study area, approximately 30 x 40 km (1200 km^2), is located northwest of the city of Campbell River on Vancouver Island, and includes the Salmon River watershed and the area bounded on the south by Campbell Lake and on the north by Highway 19 (Figure 1). This area consists of a low-elevation (0-500 m) rolling, coastal plain and a higher elevation (500-1200 m) inland mountain region. Diggle and Addison (1977) provide a detailed description of the geology, landforms, and soils of the area. Three biogeoclimatic zones, the coastal Douglas-fir (CDF), the coastal western hemlock(CWH), and the mountain hemlock (MH), occur in the study area (Krajina 1965). The area is under two major forest tenures--the Sayward Provincial Forest (SPF) and Tree Farm License (TFL) #7, held by MacMillan Bloedel Ltd. (Menzies Bay Division).

2.1 Habitat History

The first logging in the area occurred in 1869 at Elk Bay on the coast. Since then, logging has progressed from east to west across the coastal plain and into the higher elevation inland mountains where current logging activities are concentrated.

Extensive fires occurred in the study area in 1938 and 1951, burning 30 000 ha and 9000 ha, respectively. Reforestation was initiated in 1939.

The coastal plain is now dominated by 30- to 45-year-old second-growth stands of Douglas fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla), with a few small blocks of mature timber remaining. In second-growth stands, an intensive program of back-log spacing to reduce the number of trees per hectare was undertaken from 1976 to 1982. In total, 8300 ha were spaced. The debris from spacing was left on the ground, resulting in debris depths of up to 1.5 m in certain areas.

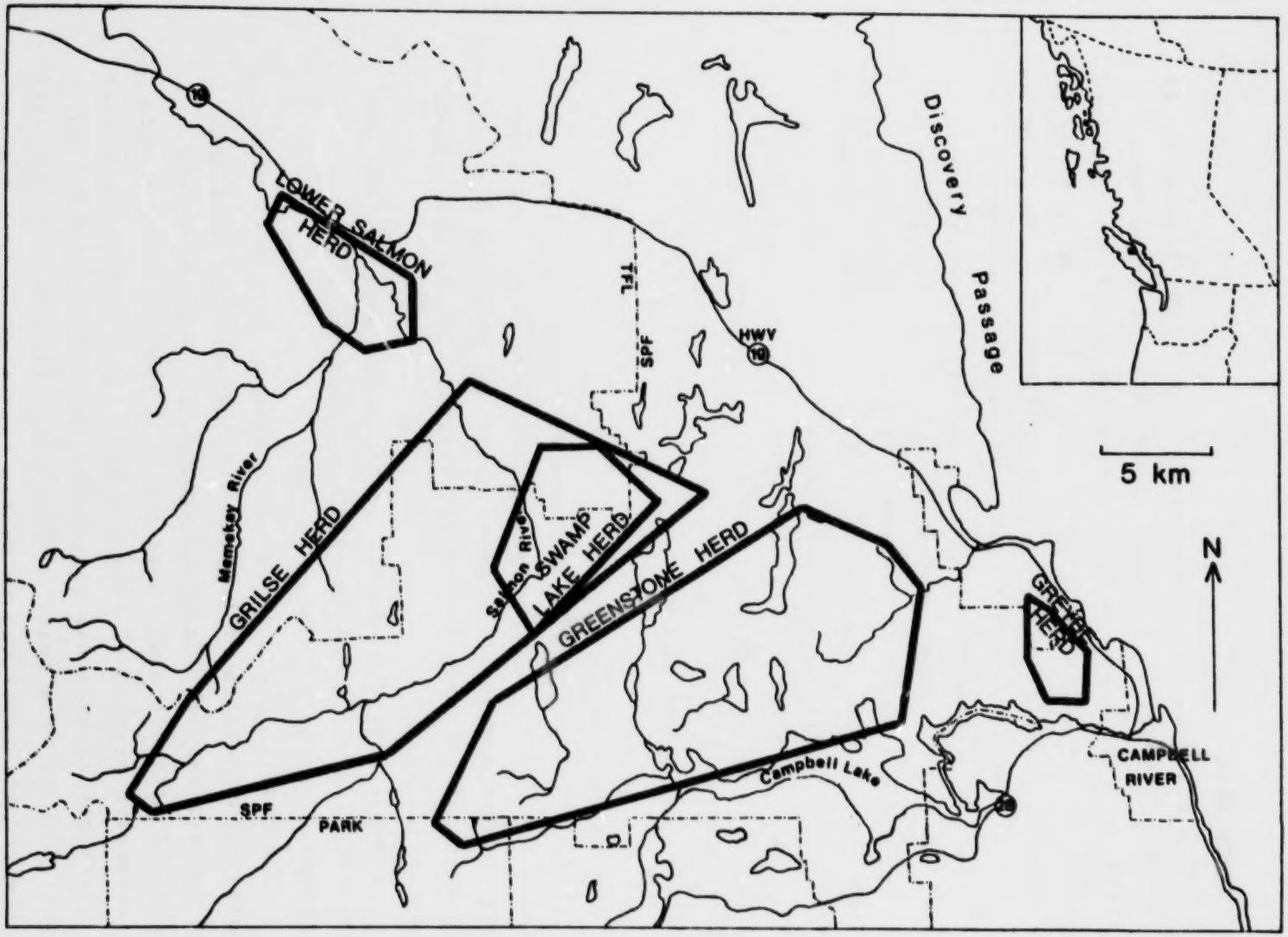

FIGURE 1. Location of the study area on northeastern Vancouver Island, showing the annual home ranges of herds in this area.

The inland mountains are dominated by mature timber and young second-growth stands (0-20 years). The current cut rate is approximately 900 ha annually.

2.2 Population History

There is scant historical information available on the elk populations in the study area. Fish and Wildlife Branch survey records date back to 1954. However, until the late 1960's, sampling effort for these surveys was low and inconsistent. Surveys during the early 1970's suggested the existence of four discrete herds: the Lower Salmon herd, estimated at 50; the Greenstone herd, estimated at 100; the Grilse herd, estimated at a minimum of 50; and the Greybe herd, estimated at 30[1]. With the exception of the Grilse herd, which is today estimated at 120-130, the 1977 estimates are similar to present 1984 estimates.

Prior to 1968 there was an open elk season on Vancouver Island, but this was closed in 1970 on the northern half of the island (including the study area). In 1977, a limited entry hunt (L.E.H.) permit system for elk was initiated. The total number of permits issued has generally increased each year. In the study area in 1984, 34 bull permits and 30 antlerless permits were issued.

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[1]D.W. Janz. 1977. Roosevelt elk in the Sayward Forest. B.C. Min. Environ., Nanaimo, B.C. Unpublished Report.

3.0 METHODS

3.1 Radiocollaring and Telemetry

Twenty-four adult cows, two yearling bulls, three adult bulls, and two calves were immobilized with a Cap-Chur gun and a combination of fentanyl citrate and xylazine hydrochloride (Hebert et al. 1982), shot from a Bell 206 helicopter. The elk were fitted with radio transmitters (Telonics Inc., Mesa, Arizona). Various body measures, blood, and a canine tooth were obtained. Diprenorphine (M50-50) was used as an antagonist to revive the elk.

From April 1981 through March 1982, elk were located approximately twice weekly by remote triangulation from roads. The accuracy of this method was tested through triangulation of randomly placed radio collars. These tests indicated that in relatively flat terrain, accuracy of the triangulation method was within 50 m of the actual location; but in steep or rolling terrain, accuracy was reduced to within 100-400 m of the actual location.

Beginning in May 1982, certain elk were selected and monitored hourly for a period of 4-10 days. These intensive monitoring sessions were carried out in May, June, and July of 1982, January and February of 1983, and January and February of 1984.

During the calving season (May and June) of 1983 and 1984, cow elk were monitored from one to four times daily to determine their calving sites.

3.2 Habitat Classification

Habitats were classified on the basis of stand type and ecosystem association (Klinka et al. 1984). Table 1 lists stand types and ecosystem associations as defined for this study. Ecosystem associations are defined on a moisture gradient.

The winter range of the Greenstone herd was stratified into stand types with the use of 1:10 000 colour air photos,

TABLE 1. Stand type and ecosystem association descriptions

Number		Description
Stand Types		
1		Non-productive (forest land) - includes bogs and rock bluffs.
2		Deciduous-conifer complex - includes deciduous-conifer mixes and pure deciduous stands.
3		1- to 20-year-old forest.
4		21- to 60-year-old forest.
5		21- to 40-year-old *spaced* forest - with 0.5-1.5 m debris depths.
6		Old growth (> 200 years old).
Ecosystem associations[a]		
Very dry	1	*Rhacomitrium* - Lichen spp.
	2	*Gaultheria*
Moderately dry	4	*Vaccinium* - *Hylocomium*
	5	Moss - *Mahonia*
Fresh	6	*Blechnum*
	7	*Polystichum* - *Achlys*
Moist	8	*Rubus spectabilis*
	9	*Sphagnum* spp.
Wet	10	*Athyrium* - *Lysichitum*
	11	*Carex* - *Myrica* - *Spiraea*

[a]After Klinka *et al.* 1984.

forest cover maps, and ground reconnaissance. Approximately fifteen 5 x 5-m permanently staked plots were placed within 200 m of road access in each stand type. Species abundance, canopy closure, soil characteristics (depth, texture, parent material, coarse fragment lithology, humus form and depth, and seepage), and site characteristics (slope position, slope, aspect, and elevation) were recorded for each plot. Species abundance was visually estimated by percent cover. For tall shrubs and conifers below 2 m, percent coverage was estimated for two layers, 0-1 m and 1-2 m. Canopy closure was estimated with a spherical densiometer (Lemmon 1956). Four readings were averaged from each of the plot corners and the plot centre and a mean plot value were then calculated from these 5 values. Site diagnosis, based on soil and site characteristics, and presence and abundance of indicator plant species, was used to group plots into ecosystem associations (Klinka et al. 1984).

Habitats on the summer range were stratified into stand types only, with the use of 1:10 000 colour air photos.

For calving sites, the following characteristics were measured or noted during 1983: elevation, habitat type, slope, terrain, aspect, understory species, overstory height, overstory age, distance to open water, distance to mature timber, distance to other vegetative cover, crown closure, and hiding cover. Hiding cover was measured with a 1.8 x 0.6-m vertically placed sighting tube (Leckenby et al. 1976). The proportion of tube obscured was recorded as a percentage at 20-m intervals from the tube along the following six compass bearings: 0°, 60°, 120°, 180°, 240°, and 300°. Measurements were taken in each direction until the tube completely disappeared from view. Field measurements at 1984 calving sites have not yet been made and present information about these sites comes from 1:10 000 air photos.

3.3 Home Range and Habitat Use Analyses

Seasonal and annual home ranges were analysed with the HOME program (Harestad 1981). Herds were defined on the basis of overlapping seasonal and annual home ranges.

Habitat selection was analysed by chi-square and Bonferroni Z (Neu et al. 1974). Availability during winter was defined as the area encompassed by the outermost radio-locations of herd animals on the winter range (December-March) over a 3-year period.

To assess habitat use, proportions of different habitat components within a home range were compared with home range size (F. Bunnell, pers. comm.).

Relationships between habitat variables (percent cover of different species and forage classes [below 2 m] and canopy closure) and stand type preference (locations per hectare) were evaluated with the use of linear regression, Spearman rank correlation, and multiple regression techniques. Normality tests of habitat data used in these analyses indicated non-normal distributions ($p<.01$).

3.4 Aerial Surveys and Population Measures

Helicopter surveys were conducted twice annually, beginning in 1982. August surveys were conducted to estimate calf:cow ratios that would serve as an index of productivity. April-May surveys were conducted to estimate calf:cow ratios that would serve as an index of recruitment. Sample sizes were derived with the formula (Cochran 1977):

$$n = \frac{N_0}{1 + (N_0/N)}$$

where: $N_0 = t^2\left(\frac{pq}{d^2}\right)$

N = estimated herd size
n = sample size required
t = the t-value for the appropriate confidence interval
p = the calf:100 cow ratio
q = 1-p
d = the maximum desired error (3%) in the calf:100 cow ratio.

Population estimates were made based on composite information from Petersen index calculations (Seber 1973) and general knowledge of the herds from extensive aerial surveys conducted during 1981/82.

Calf survival was estimated from August to April from calf:cow ratios in both months. Calf survival estimates were adjusted based on the estimated cow survival rate over the same period (Purdy 1984).

3.5 Examinations of Hunter Collected Samples

Kidney, tooth, and female reproductive tract samples were collected from elk harvested in the study area during the fall hunting seasons of 1981, 1982, and 1983.

Incisors were sectioned and aged based on cementum annuli by Matson's Ltd. Mill Town, Montana.

The kidney fat index (KFI) was calculated from hunter samples using the formula (Riney 1955):

$$\text{kidney fat index} = \frac{\text{perinephric fat weight}}{\text{kidney weight}} \times 100.$$

A significant relationship between KFI and total body fat has been demonstrated in seven species of East African ungulates (Smith 1970), and Riney's method has been used extensively as an indicator of plane of nutrition (Hanks 1981).

Female reproductive tract samples were analysed for the presence of a fetus. Samples collected prior to November were not included in analyses because earlier pregnancies may not have been detectable with the use of normal macroscopic methods. Fetus size (crown to rump length) was used to estimate conception date (Trainer 1971).

3.6 Diet Composition and Quality Analyses

Fresh pellet samples were collected from groups of elk containing radio-collared individuals as often as possible (a minimum of once monthly per herd). Composite diet samples were prepared on a seasonal and herd basis. Fecal samples collected in 1984 winter were not lumped, but were analysed for each collection date.

Diet composition was estimated by fecal fragment analysis (Sparks and Malechek 1968; Ward 1970; Davitt and Nelson 1980). Forage voucher slides of approximately 50 species, collected and prepared for a previous study on Vancouver Island (Janz 1983), were used in the identification of epidermal fragments. Percent species composition of diets were determined with the use of eight slides of fecal material and 300 fields of view for each diet.

A gridded eyepiece was used to count the percent of area covered by each species in each field of view. Percent coverages were totalled to calculate percent of diet by species. Diet sample analyses were done at the Wildlife Habitat Laboratory, Washington State University, Pullman, Washington.

Diet selection was analysed based on ranks by usage and availability (Johnson 1980). Estimates of availability of species on the winter and summer range were made by totalling stand type species cover values, which had been adjusted by the percent of the winter or summer range that each stand type represented.

Fecal nitrogen (N) or fecal crude protein (N x 6.25) was used as an indirect index of diet quality. Significant correlations between fecal crude protein and measures of diet quality have been reported for bighorn sheep (Hebert 1973) and Roosevelt elk (Janz 1983). Fresh pellet groups were collected from radio-collared groups over the annual cycle and analysed for fecal nitrogen by the Wildlife Habitat

Laboratory, Washington State University. Dietary protein levels during winters were estimated from fecal crude protein values with the regression developed by Janz (1983):

$$Y = 0.71X$$

where Y is dietary crude protein, and X is fecal crude protein.

Diaminopimelic acid (DAPA), an indigestible by-product of rumen fermentation, was used as an indicator of digestible energy levels in diets. Nelson et al. (1982) have found, in controlled studies, that DAPA levels in fecal samples were directly related to diet digestible energy. DAPA analyses were performed by the Wildlife Habitat Laboratory, Washington State University.

Twenty-five forage species collected during January and February of 1984 were analysed for tannin content (mg/g) by the Ministry of Environment, Environmental Soils Laboratory, Kelowna, B.C. Quantitative techniques from Hagerman and Butler (1978) were followed in all tannin assessments.

3.7 Weather Monitoring

Two CR-21 weather stations (Campbell Scientific Ltd., Edmonton, Alberta) were used to monitor temperature, wind speed, and wind direction continuously. November through March (1982/83 and 1983/84), these stations were placed in open sites at the southern and northern ends of the Greenstone herd winter range. May through September (1983 and 1984), the stations were moved onto summer range. In the 1983 summer, one station was placed in an open 15 year old second growth stand and one in an adjacent mature timber stand on the Grilse herd summer range to compare temperature and wind speeds. In the 1984 summer, both stations were located in the open, one on the low-elevation (400 m) summer range of a resident herd and the other on the higher elevation (750 m) summer range of the Grilse herd.

During winters, snow depths were measured in the open at permanently staked road locations. At each location, four measurements were taken and averaged.

A winter severity index was computed based on annual snow depth profiles from Janz (1983) and this study by dividing the area under each snow depth curve by the area under the curve for the winter of 1977 (Janz 1983).

3.8 Activity Monitoring

Elk activity was recorded with a Rustrak recorder from tip-switch collars during the winter monitoring sessions, 24 hours a day. During the first two sessions in 1983, activity was not monitored due to receiver failure. Activity strip charts were divided into 1/10-hour intervals and analysed manually for inactive and active signals based on amplitude and pulse rate information.

Simultaneous observation-activity recording done on captive elk at the Vancouver Game Farm, Cloverdale, B.C. showed that active recorded signals were indicative of active behaviours (grazing, browsing, standing, and travelling), and inactive recorded signals were indicative of inactive behaviours (bedding, ruminating, and standing). Gillingham and Bunnell (1984), studying activity of black-tailed deer, found that tip-switch collars recorded active:inactive ratios correctly (compared to observed activity) 90% of the time.

3.9 Predation Analyses

Wolf and bear sign observations were recorded during regular road use and used as indicators of predator density.

Wolf scats (n=95), collected from April through August 1983, were autoclaved and microscopically analysed for major prey items (Becker 1982). Relative percent weight of prey species in the diet was estimated with the regression equation from Floyd et al. (1978):

$$Y = 0.38 + 0.02X$$

where Y was the kilogram of prey per collectable scat and X was the average weight of an individual of a given prey type.

4.0 RESULTS AND DISCUSSION

Results and discussion of data collected from April 1981 to June 1984 are presented here.

4.1 Winter Severity

Based on snow depth, the winter of 1982 was the most severe (Figure 2); with snow accumulations >60 cm on the winter range. However, compared to snow depth information collected at a similar elevation on Vancouver Island in the 1970's (Janz 1983), 1982 was only a moderate winter. Both 1983 and 1984 were mild winters.

4.2 Home Ranges and Migration

There are both migratory and non-migratory (resident) herds in the study area (Figure 1). The two largest herds, the Grilse and the Greenstone, are migratory. There are three known non-migratory herds, but it is suspected that there may be others. The non-migratory herds are, in

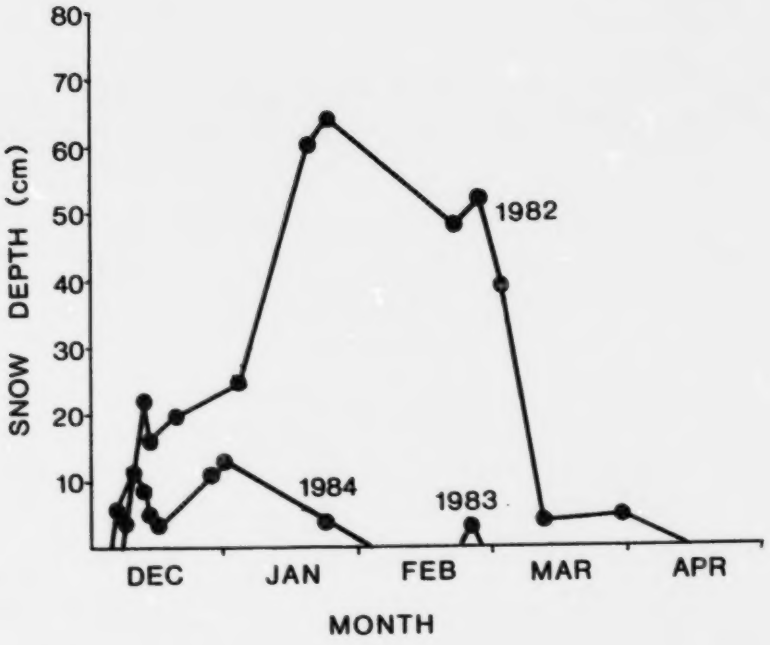


FIGURE 2. Accumulated snowpack for Mohun Lake (200 m), 1982-1984.

general, smaller than the migratory herds and spend the entire year at low elevations (50-300 m). Two of the non-migratory herds occupy areas that are also winter ranges for migratory herds.

The migratory herds winter at low elevations (90-370 m) and summer at higher elevations (425-1370 m). Parameters of migration for the Grilse and Greenstone herds are summarized in Table 2. The time spent in transition between summer and winter ranges varies between individuals and years. However, time spent on transitional ranges is generally less than two months annually.

Annual home range sizes (Table 3) of migratory elk were approximately six times larger than those of non-migratory elk. Summer home ranges varied in size from 2.2 to 30.1 km^2.

Most collared elk displayed high fidelity to seasonal ranges over the study period. However, several examples of long-distance movement from or between herds occurred during the study. In one case, a 5-year-old cow that wintered with the Greenstone herd, spent the summer and breeding seasons with a different herd (in the Heber River), a straight-line distance of 42 km. This pattern was repeated for 3 years. In another example, an 18-year-old cow that spent the summer and winter with the Grilse herd for 3 years, migrated to the Elk River watershed for the mild winter of 1984. After eight months, she returned to her previous range.

4.3 Population Estimates

Population density (Table 4) varies by herd and season. The migratory herds (Grilse and Greenstone) have the highest summer densities, 3.5-6.5 elk per square kilometer. Winter densities are similar on all ranges, approximately 3-4 elk per square kilometer. The winter density estimate for the Lower Salmon herd (1.6 elk per square kilometer) probably underestimates actual density because a migratory herd (of unknown size) has an overlapping winter range.

TABLE 2. Parameters of migration for the Grilse and Greenstone herds

	Grilse herd			Greenstone herd		
	Summer range (Grilse Ck. & Gold Lk.)	Winter range (Lower Salmon)	Transitional range (Bootfrog Lk.)	Summer range (Upper Greenstone)	Winter range (Cranberry Loveland)	Transitional range (Lawson & Patterson Lk.)
Elevation (m)	425-550/550-1370	90-370	460-730	850-1070	60-300	180-300
Time spent on the range	5-7 months	4-6 months	1-2 months	5-7 months	4-6 months	1-2 months
Disturbances	Grilse Ck. - approx. 50% of the area logged. Regen. aged 1-10 yrs. No spacing. Gold Lk. - undisturbed natural slide area.	Approx. 90-95% of area logged. Regen. aged 8-45 years. Limited spacing 10-15 years ago.	Almont totally logged. Regen. aged 10-20 years Moderate amounts of spacing treated 5-8 years ago.	Approx. 50-75% of area logged. Regen. aged 2-10 years. No spacing.	Approx. 95% of area logged. Regen. aged 5-50 years. (Most is 35-45 yrs.) Many large blocks of backlog spaced stands treated over the last 2-10 years.	Approx. 90% of area logged. Regen. aged 20-35 years. Some large backlog spaced stands treated over the last 5-10 years.
Migration Distances (straight line)	Summer to winter range 18-26 km	Winter to trans. range 8 km	Trans. to summer range 10-18 km	Summer to winter range 17 km	Winter to trans. range 8-12 km	Trans. to summer range 5-8 km
Comments	Grilse Ck. - wide valley bottom around main drainage creek. Steep walled valley sides of general N and S aspect. Several very large and many smaller bogs interspersed with mature timber. Gold Lk. - very steep subalpine mature timber/slide alder complex. Mostly N and S aspect.	Very wide (3-5 km) valley bottom with many bogs is Salmon R. flats; gentle slopes with variable aspect elsewhere.	Steep E aspect. Some small bogs on flat benches.	Mostly sheep E aspect with many bogs on flat benches.	Gentle slopes of variable aspect. Steeper areas S aspect.	Some very large bog Myrica/Spiraea areas.

TABLE 3. Annual and seasonal home range size estimates for adult cows in four herds

Herd	Animal No.	Home range size (km^2)		
		Annual	Summer	Winter
Grilse	41	164.4	4.0	6.6
	221	167.1	9.5	30.1
	252	137.1	3.5	43.8
	271	155.5	11.1	19.6
	391	130.5	4.4	
	1038		6.6	2.2
	Mean	150.9	6.5	20.5
Greenstone	262	152.1	29.2	9.9
	490[a]	862.6		2.2
	591	266.0		2.8
	641	149.6		9.9
	Mean[b]	189.2		6.2
Lower Salmon	342	23.7		
Greybe's	61	10.5		

[a] 490 winters with the Greenstone herd, but summers in the Heber River, 42 km away.

[b] The annual home range of No. 490 was excluded from this mean.

TABLE 4. Annual and seasonal herd area and density estimates for four herds in the study area

Herd	N[a]	Herd range area (km^2)			Herd density (elk/km^2)[b]		
		Annual	Summer	Winter	Annual	Summer	Winter
Grilse	130	200	20	30	0.6	6.5	4.3
Greenstone	90	150	25	30	0.6	3.6	3.0
Lower Salmon	40	25	25	25	1.6	1.6	1.6[c]
Greybe's	30	10	10	10	3.0	3.0	3.0

[a] 1983 population estimates of total number of cows and calves in the herd are based on composite information from Peersen-index calculations (based on ratio of radio-collared elk seen to radio-collared elk present), radiotelemetry, and general knowledge of the herd.
[b] Density estimates are for cow-calf groups, and exclude adult bulls.
[c] Densities may be higher than this during winter, as a migratory herd (of unknown number) shares the same winter range.

4.4 Age Structure

Pooled age estimates from tooth samples of radio-collared elk (n=30) and harvested elk (n=90) for a 3-year period provided age structure data (Figure 3). The first three age classes in this sample are underestimated because they have been sampled less than 3 years, and also because there was a capture and hunting bias for adults and larger animals, respectively. Sample size for females was too low to construct a life table (Caughley 1977).

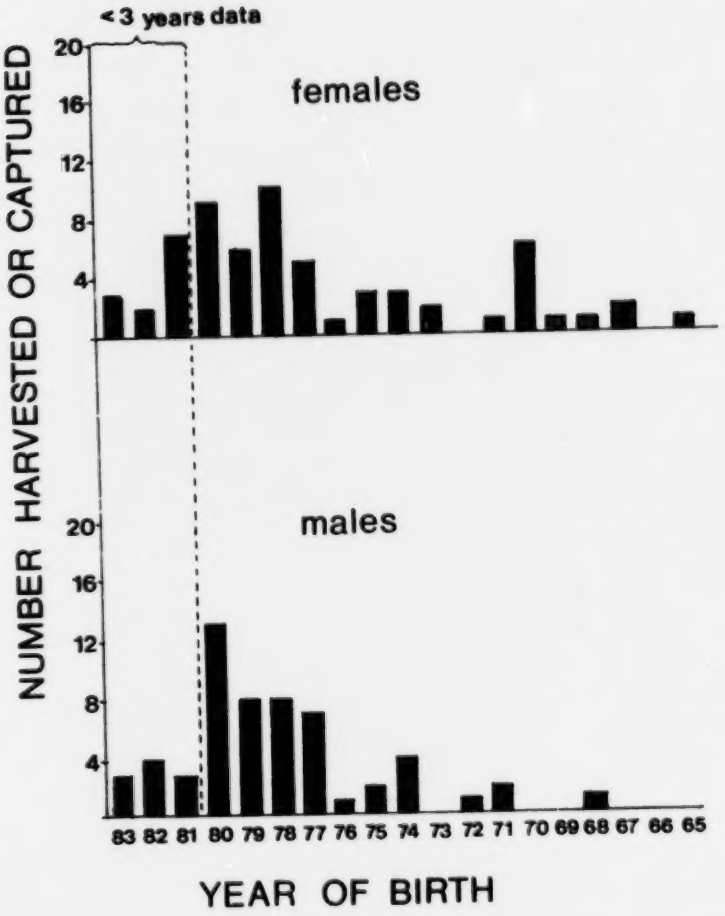


FIGURE 3. Age structure of male and female populations in the study area from captured and harvested animals.

4.5 Production

Calf production, as indexed through summer calf:cow ratios, was comparable between the Grilse and Greenstone herds in all years except 1983 (Table 5). The decreased calf:cow ratio in the Grilse herd may have been due to increased wolf predation on calves during the summer of 1983.

Comparison of calf:cow ratios collected in the study area with those from other studies (Harn 1960; Follis and Spillet 1974; Kimball and Wolfe 1979; Kuttels 1975; Janz 1980) indicates no major differences (Table 6).

Examination of reproductive tract samples from harvested elk cows, 2 1/2 years and older, indicated 13 of 17 were pregnant. In a larger sample from Vancouver Island (n=38), Janz (1980) estimated a pregnancy rate of 89.5% for cows 2 1/2 years and older.

Conception dates, estimated from fetal sizes and kill dates (Trainer 1971), ranged from September 10 to October 16.

Assuming a gestation period of 250-265 days (Harper 1971), parturition would occur between May 18 and July 6. Field observations suggest that most calving activity occurs between May 20 and June 15.

4.6 Survival

Spring calf:cow ratios (Table 7) correlated with winter severity ($p<.02$) when the 1984 Grilse herd value was excluded. (The Grilse herd value was not expeced to fit this relationship as calf:cow ratio were already depressed during the previous summer, possibly due to predation.) With additional data from Janz (1983) used, spring calf:cow ratios were significantly related to winter severity, both including 1984 Grilse herd values ($r^2 = 0.69$) and excluding them ($r^2 = 0.94$)(Figure 4).

TABLE 5. Summer calf:cow ratios for the Grilse and Greenstone herds

Year	Herd	Number classified	Adult bulls	Yearling bulls	Cows	Calves per 100 cows: Calves	80% CI[a]	Mean
1982	Grilse	121	5	7	73	36	47-51	49
	Greenstone	69	6	5	39	19	44-53	49
1983	Grilse	131	4	9	86	32	35-39	37
	Greenstone	72	1	4	43	24	52-60	56
1984	Grilse	143	8	10	86	39	44-46	45
	Greenstone	67	8	5	37	17	40-52	46

[a]80% confidence interval

TABLE 6. Comparative summer calf:cow ratios from this and other studies

Author	Location	Subspecies	n[a]	Calves/100 Cows Mean	80% CI
Harn 1960	N. California	roosevelti	5	30	1-59
Follis and Spillet 1974	Utah	nelsoni	2	54	
Kimball and Wolfe 1979	N. Utah	nelsoni	9	51	47-55
Kuttels 1975		roosevelti	4	54	22-85
Janz 1980	Vancouver Island	roosevelti	5	49	43-55
This study	Vancouver Island	roosevelti	7 8	50 49	44-57[b] 40-58[c]

[a]Represents the number of calf:cow ratios estimated (from one or several herds for one or several years).
[b]Excluding Grilse herd values in 1983.
[c]Including Grilse herd values in 1983.

TABLE 7. Spring calf:cow ratios for the Grilse and Greenstone herds

Year	Herd	Number classified	Adult bulls	Yearling bulls	Cows	Calves	Calves per 100 cows	% Calf loss from previous summer count[a]
1982	Grilse	148		8	107	33	31	
	Greenstone	78	4	4	53	17	32	
1983	Grilse	110		8	73	29	40	18
	Greenstone	88	13	2	51	22	43	12
1984	Grilse	79	3	3	58	15	26	30
	Greenstone	49	8	2	27	12	44	21

[a]Assuming 100% cow survival; 1982 values could not be estimated because counts were not made during the summer of 1981.

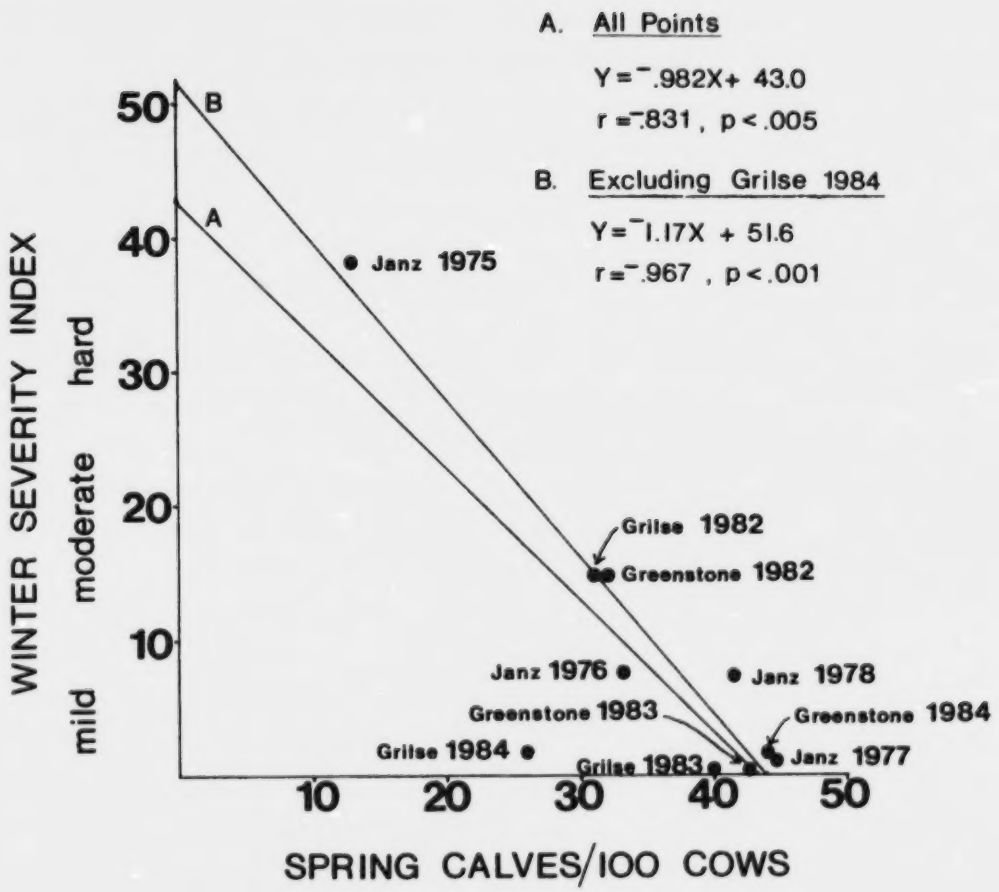


FIGURE 4. Relationship between spring calf:cow ratios and winter severity. Additional data from Janz (1983).

Calf survival, August through April, ranged from 65 to 80% during the two mild winters (Table 8). Survival of calves from birth (May and June) to August was not estimated, though it is during the first three months that high mortality, particularly predation, can occur. If the estimated pregnancy rate (76%) is used to estimate May-June calf production, then there is potentially 36-51% calf mortality occurring by August and an annual survival rate of calves ranging from 31 to 53%.

4.7 Predation

Wolf scat analysis (Becker 1982) for scats collected April through August 1981 indicated that elk comprised 57.7% (11.0% calves, 46.7 % adults) of the wolves' summer diet on a relative weight basis (Figure 5). Based on an assumed minimum food intake requirement of 1.7 kg food per wolf per day (Mech 1977), one wolf would have consumed 0.8 calves and 0.5 adults over the summer period (Table 9).

4.8 Condition Indices

Kidney fat indices (KFI) declined from 1981 to 1982, but increased again in 1983 (Table 10). Values obtained in 1982 were significantly different from values in 1981 and 1983 ($p<.05$). The decline in the KFI in 1982 corresponds with an increase in the winter severity in the same year (Table 10).

Fecal crude protein (FCP) showed seasonal patterns, peaking in spring and declining to lowest values in mid-winter, comparable to other studies (Gates 1980; Hanley 1980; Leslie 1982; Janz 1983)(Figure 6). However, FCP peak values were higher than those reported in other studies. Also, lowest FCP values, with the exception of the 1982 winter, were higher than those found in other studies.

TABLE 8. Calf survival, August to April, during 1983 and 1984 for the Grilse and Greenstone herds

Year	Herd	Mean August cow:calf ratio	Mean April cow:calf ratio	Adult survival[a] estimate Aug-April	Apparent calf survival	Corrected[b] calf survival
1983	Grilse	49	40	.926	.82	.76
	Greenstone	49	43	.920	.87	.80
1984	Grilse	37	26	.926	.70	.65
	Greenstone	55	44	.920	.80	.74

[a]Adult cow mortality estimated from radio-collared animal mortalities and harvest records during 1981 and 1982 (Purdy 1984).
[b]Corrected for adult mortality.

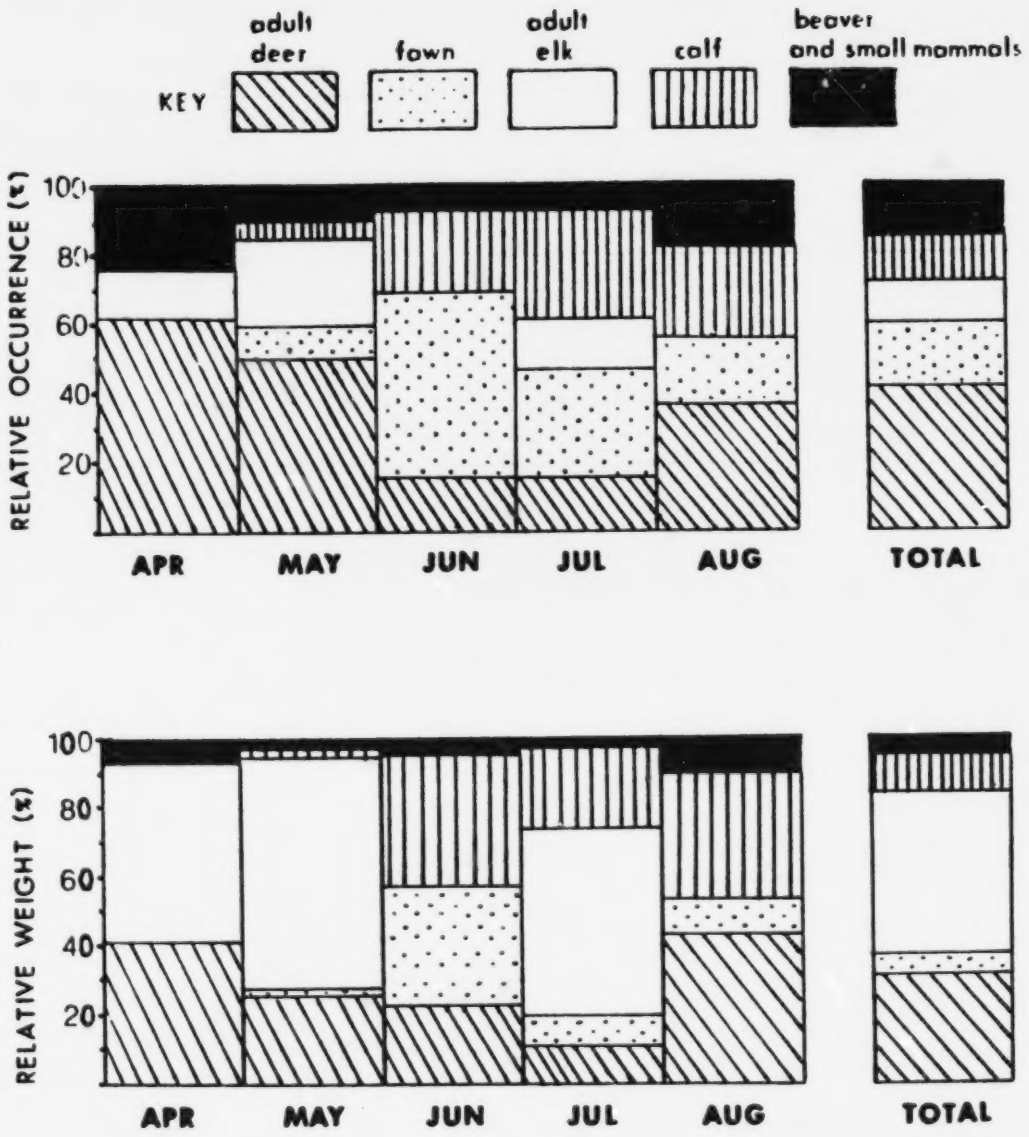


FIGURE 5. Contents of wolf scats (n=95) collected along logging roads, represented as both frequency of occurrence (%) and relative weights (%).

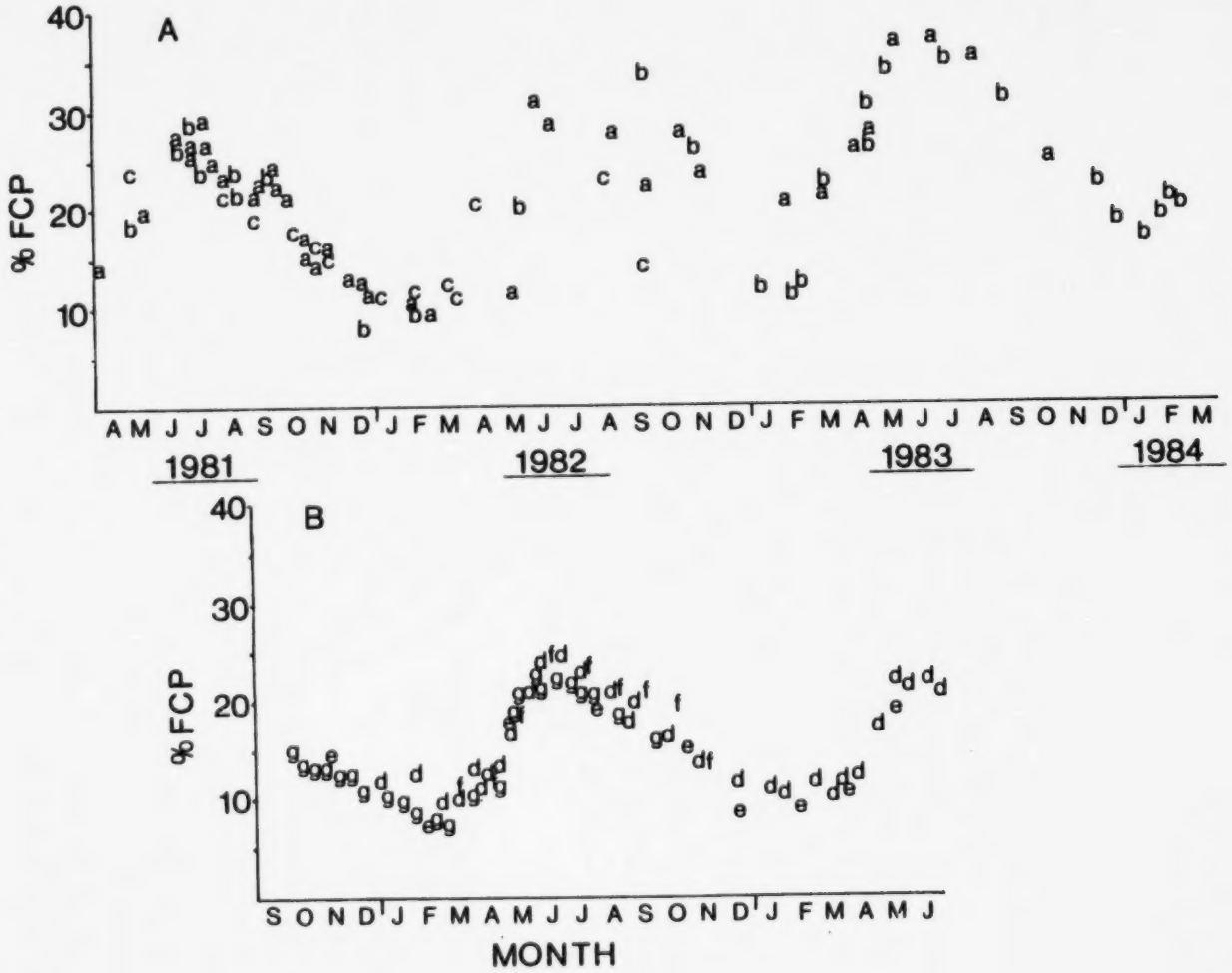
TABLE 9. Estimated number of elk calves and adults consumed per wolf between April and August 1981, based on mean weight consumed per scat (Adapted from Becker 1982)

Variable	Calves	Adults
A. Estimated mean weight consumed per scat[a]	1.3	6.0
B. Frequency of occurrence (%)	13.4	12.2
C. Relative weight	14.1	59.5
D. Relative % of total biomass consumed	11.0	46.7
E. Estimated weight of prey consumed in summer for one wolf (153 days)	28.6	121.4
F. Estimated mean consumable weight (kg) of individual prey[c]	36.0	222.8
G. Number of individuals eaten per wolf	0.8	0.5

[a]From Floyd et al. (1978) equation, Y = 0.38 + 0.02x.
[b]Assuming 1.7 kg food/wolf/day.
[c]Calculated at 0.80 x total weight for elk calves and adults (Fuller and Keith 1980).

TABLE 10. Annual kidney fat index (KFI), fecal crude protein (FCP), and winter severity values from this study and Janz (1983)

Author	Year	Winter severity	Late-Winter calves per 100 cows	Winter FCP	Fall KFI
This study	1981	<1.0 (no snow)	--	--	104.9
	1982	15.3	31.5	7.5	40.5
	1983	0.2	41.5	11.5	103.4
	1984	1.6	35.0	19.0	--
Janz	1975	38.0	13.0	9.1	--
	1976	7.8	33.0	11.5	--
	1977	1.0	44.6	11.6	--
	1978	7.4	41.5	11.0	--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MONTH

FIGURE 6. Fecal crude protein profiles for (A) the herds in this study (a = Grilse, b = Greenstone, c = Lower Salmon) and (B) other elk studies (d = Janz [1983], e = Leslie [1982], f = Hanley [1980], g = Gates [1980]).

Relatively high FCP values may be attributed to high tannin content of species in the diet (Table 11). Tannins are secondary plant compounds that interfere with protein digestibility by forming indigestible complexes with proteins and enzymes (Mould and Robbins 1981), thereby increasing the nitrogen or protein content of the feces.

During the winter, dietary crude protein levels declined to 8% in 1983 and 13% in 1984. These values are well above the critical maintenance value of 5% suggested by Mould and Robbins (1981).

Diaminopimilic acid (DAPA) values, though collected only for a single year, show a similar pattern to FCP except that the seasonal peak DAPA values occur one month earlier in three of four herds compared to FCP values (Figure 7).

4.9 Diet Composition

Food habits varied with herd and season (Tables 12-15). Ferns, such as Blechnum spicant and Polystichum munitum, and graminoids comprised the bulk of spring foods. Conifers and shrubs were also important as spring foods. During summer, use of conifers declined to 5% or less in all herd diets (Figure 8). Shrubs such as Rubus spp., Sambucus racemosa, and Cornus canadensis became important during the summer. The use of graminoids remained high in summer, whereas the general use of ferns declined. In the migratory herds during the fall, use of conifers and ferns increased, while the use of graminoids declined. In non-migratory herds, the use of graminoids remained high during this season. For example, in the fall of 1981, grasses comprised 63% of the estimated diet of the Greybe herd, probably because farms with hay pastures dominate a large part of this herd's range. Winter diets shifted to heavy use of conifers, especially Tsuga heterophylla and Thuja plicata, and the taller shrub species,

TABLE 11. Tannin (mg/g) content of some selected species collected on the Greenstone winter range in January 1984

Forage class	Species	Part	Tannin (mg/g)
Conifers	Pinus contorta	bark	8.33
	Picea sitchensis	stems and needles[a]	4.11
	Tsuga heterophylla	stems and needles	4.01
	Pseudotsuga menziesii	stems and needles	3.04
	Thuja plicata	stems and needles	2.72
	Pinus monticola	stems and needles	2.11
Shrubs	Salix sp.	bark	5.29
	Alnus rubra	bark	3.13
	Gaultheria shallon	stems and leaves	2.72
	Rubus ursinus	stems and leaves	2.58
	Salix sp.	stems	2.22
	Myrica gale	stems	0.76
	Alnus rubra	stems	0.56
	Rosa gymnocarpa	stems	0.53
	Mahonia nervosa	stems and leaves	0.44
	Rubus spectabilis	stems	0.40
	Vaccinium parvifolium	stems	0.15
	Oplopanax horridum	stems	0.11
Forbs	Cornus canadensis	leaves	2.15
	Linnaea borealis	stems, leaves and stolons	0.16
Ferns	Polystichum munitum	fronds	1.01
	Blechnum spicant	fronds	0.63
Graminoids	Juncus sp.	stems and leaves	0.60
	Carex sp.	stems and leaves	0.45
	Luzula sp.	stems and leaves	0.44
	Grasses	stems and leaves[b]	0.22

[a] Stems of shrubs and trees were the terminal 8-10 cm of stem.
[b] Stems and leaves of grasses collected were a mixture of dead (brown) and green material.

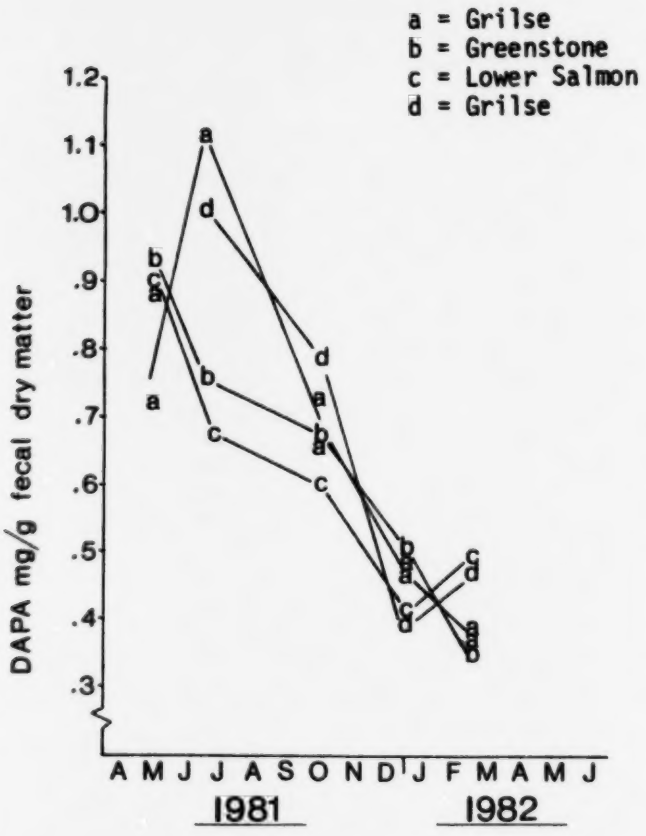

FIGURE 7. Diaminopimilic acid (DAPA) profiles for four herds in this study.

TABLE 12. Percent spring diet composition by herd during 1981

	Migratory herds		Non-migratory
	Grilse	Greenstone	Lower Salmon
Plant taxa	1981	1982	1981
Conifers			
Tsuga heterophylla		10.2	6.2
Thuja plicata	1.8	0.8	
Abies amabilis	4.5	6.0	
Taxus brevifolia	14.4		0.4
Shrubs			
Cornus canadensis	7.9	0.6	0.1
Rubus spp.	7.1	8.7	8.8
Physocarpus sp.	3.5		3.2
Vaccinium sp.	3.2	3.3	1.5
Sambucus sp.		0.1	1.1
Alnus rubra	0.2	2.2	0.3
Salix sp.		0.9	
Gaultheria shallon		0.3	
Unknown			4.0
Forbs			
Lysichitum sp.	1.6	0.2	
Linnaea borealis		3.5	
Hypochaeris radicata			1.4
Unknown			2.1
Graminoids			
Grasses	15.5	14.6	28.5
Sedges	6.9	0.8	8.0
Ferns			
Polystichum munitum	7.2	6.4	34.4
Blechnum spicant	26.2	41.3	
Athyrium filix-femina		0.1	
Number of identified species	13	17	14

TABLE 13. Percent summer diet composition by herd during 1981

	Migratory herds		Non-migratory	
	Grilse	Greenstone	Lower Salmon	Greybe's
Plant taxa	1981	1981	1981	1981
Conifers				
Tsuga heterophylla	0.6		3.8	1.7
Thuja plicata			1.3	1.2
Abies amabilis	2.0	4.3		
Taxus brevifolia	1.7	0.1		
Shrubs				
Cornus canadensis	2.2	0.4		33.9
Physocarpus sp.	6.8	3.4	4.1	6.8
Rubus spp.	44.3	6.9	2.8	2.6
Sambucus sp.	23.3		0.7	0.3
Salix sp.			0.5	
Vaccinium sp.	0.1	0.3	1.3	2.3
Gaultheria shallon		0.5		0.1
Ribes sp.	2.1			
Unknown		44.0	36.3	
Forbs				
Lysichitum sp.	2.3	2.6	5.5	11.7
Mycelis muralis[a]	1.1	7.1	7.3	14.3
Veratum sp.				2.9
Aruncus sylvester				0.4
Hypochaeris radicata		0.2	0.4	
Tiarella trifoliata		1.1		
Graminoids				
Grasses	9.9	18.1	12.8	8.7
Sedges	2.5	6.2	1.2	0.3
Ferns				
Polystichum munitum		0.9	9.4	2.7
Athyrium filix-femina	0.4		12.5	7.1
Blechnum spicant			0.3	0.3
Unknown		3.8		2.4
Equisetum sp.	0.7	0.2		
Number of identified species	15	17	16	18

[a] formerly named *Lactuca muralis*

TABLE 14. Percent fall diet composition by herd during 1981

	Migratory herds		Non-migratory	
	Grilse	Greenstone	Lower Salmon	Greybe's
Plant taxa	1981	1981	1981	1981
Conifers				
Tsuga heterophylla		3.4	11.9	0.6
Thuja plicata	3.0	3.2	12.7	16.1
Abies amabilis	16.7	14.0	0.1	
Shrubs				
Rubus spp.	6.3	4.5	8.1	8.9
Cornus canadensis	32.0	5.4	1.6	
Vaccinium sp.	0.4	0.1	1.0	
Alnus rubra			1.4	
Gaultheria shallon	0.4	1.5	0.3	0.3
Physocarpus sp.	0.1		0.1	
Myrica gale			1.4	
Symphoricarpus sp.		0.6		4.0
Mahonia nervosa		0.3		
Lonicera sp.		3.7		
Unknown			15.0	
Forbs				
Linnaea borealis	2.9	2.0		2.0
Mycelis muralis[a]	6.1	0.4	15.2	
Epilobium angustifolium	3.6	0.3	0.5	
Lysichitum sp.	3.3	0.3	0.5	
Graminoids				
Grasses	0.3	0.2	20.7	62.9
Sedges	0.1	0.2	0.6	1.0
Ferns				
Polystichum munitum	0.4	2.2	4.6	0.1
Blechnum spicant	24.4	57.1	1.7	3.8
Athyrium filix-femina		0.6	2.6	0.3
Number of identified species	15	19	19	11

[a] Formerly named *Lactuca muralis*

TABLE 15. Percent winter diet composition by herd and year

Plant taxa	Grilse herd		Greenstone herd			
	Dec-Jan 1981/82	Feb-Mar 1982	Dec-Jan 1981/82	Feb-Mar 1982	Jan-Feb 1983	Dec-Jan-Feb 1983/84
Conifers						
Tsuga heterophylla	4.2	4.2	26.1	13.0	23.9	19.9
Pseudotsuga menziesii		0.5				0.9
Thuja plicata	14.8	7.1	9.6	40.8	1.2	3.2
Abies amabilis	4.3		5.3	1.8		
Taxus brevifolia		1.0				
Pinus sp.						0.1
Shrubs						
Gaultheria shallon	9.6	9.1	12.1	7.2	3.4	9.0
Mahonia nervosa		2.8	3.3	6.0		2.9
Vaccinium sp.	4.3	8.4	2.7	8.9	3.1	0.4
Arctostaphylos uva-ursi						0.4
Salix sp.	4.3					
Alnus rubra	1.5				0.3	
Rubus spp.		1.6			0.9	
Ribes sp.					0.4	
Myrica gale					0.5	
Unknown		1.3	0.5			
Forbs						
Linnaea borealis	17.2	14.5	22.0	12.6	14.1	19.2
Lysichitum sp.					0.9	
Achlys sp.					0.2	
Mycelis muralis[a]	0.5					
Viola sp.					0.1	
Graminoids						
Grasses	0.7	0.3	8.8	6.8	20.2	9.4
Sedges		5.3	0.4		11.9	20.0
Ferns and fern allies						
Blechnum spicant	34.1	29.5	6.6	1.6	8.7	5.9
Polystichum munitum	4.5	12.2	1.6		2.5	2.3
Athyrium filix-fem.		1.2	0.6		3.3	0.2
Pteridium aquilinum			0.4		0.4	
Equisetum sp.		0.2			3.8	
Bryophytes						
Lichen		0.8		1.3	0.2	0.2
Number of identified species	12	17	14	10	20	15

[a] Formerly named *Lactuca muralis*

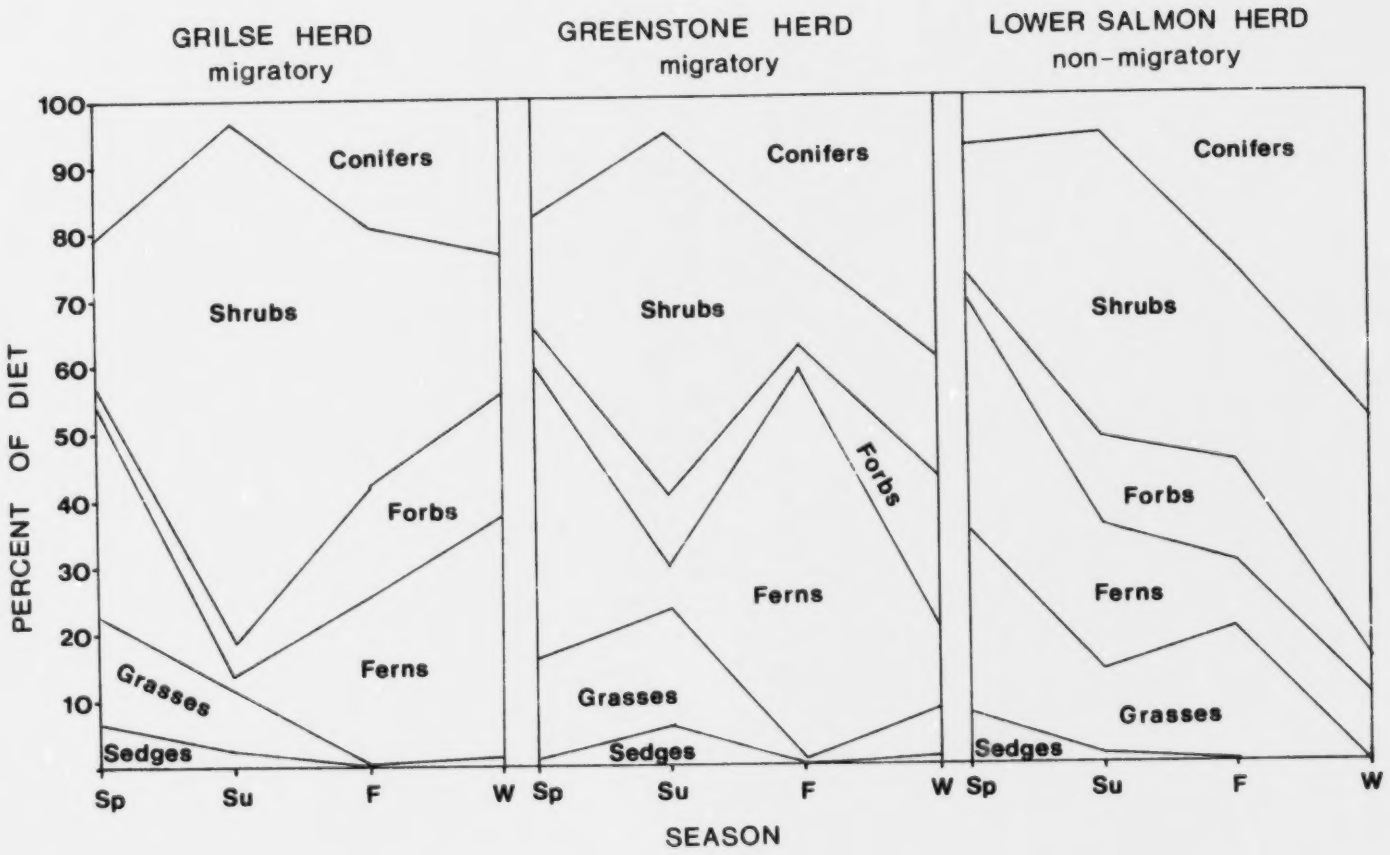

FIGURE 8. Seasonal diet trends by forage class for three herds from spring 1981 through winter 1982.

Vaccinium sp., Mahonia nervosa, Salix sp., and Gaultheria shallon. Ferns, especially Blechnum spicant, and sedges were also important during the winter.

Rank comparisons of usage and availability (Johnson 1980) of species on the Grilse Creek summer range in 1981 indicate the relative preference of plant taxa during the summer (Table 16). However, a Spearman rank correlation between use and availability was significant ($p<.10$), indicating that use of forage species increased proportionally with availability and that selection or preference may not have been an important factor in diet composition during summer.

Rank comparisons of usage and availability of species on the winter range in 1983 and 1984 indicate that Blechnum spicant, grasses, Linnaea borealis, Tsuga heterophylla, and sedges were the preferred plant taxa during both winters (Table 17). However, these preferences would probably shift during a winter with significant snow accumulations.

Detailed study of winter diets for the Greenstone herd ($n=10$) indicates a relationship between snow cover and diet composition (Figure 9). As snow depths increase, the proportion of conifers in the diet increases and the proportion of graminoids decreases. This shift in diet is generally related to a shift in habitat use. During mild, snow-free periods, there is high use of bogs and wet areas where graminoids are abundant, while during colder periods with snow cover, there is high use of south slopes where graminoids are less abundant. Gates (1980) found a similar shift from grazing to browsing at snow depths greater than 30 cm.

TABLE 16. A rank usage-availability comparison between species composition in the summer diet and availability on the Grilse herd summer range, 1981

Forage Class	Species	Rank		Difference	Relative preference
		Use	Availability		
Conifers	Tsuga heterophylla	12.5	7	5.5	15
	Thuja plicata	9.5	24	-14.5	2
	Abies amabilis	5.5	8.5	-3	8
	Pseudotsuga menziesii	19.5	5	14.5	20
Shrubs	Rubus spp.	1	6	-5	6
	Cornus canadensis	2	3	-1	9
	Vaccinium spp.	12.5	2	10.5	19
	Myrica gale	19.5	4	15.5	21
	Mahonia nervosa	4	11.5	-7.5	4
	Ledum groenlandicum	19.5	19	.5	11
Forbs	Achlys triphylla	19.5	16	3.5	14
	Tiarella trifoliata	19.5	20.5	-1	9
	Streptopus amplexifolius	19.5	22.5	-3	8
	Clintonia uniflora	19.5	18	1.5	12
	Linnaea borealis	9.5	14	-4.5	7
	Mycelis muralis[a]	7	22.5	-15.5	1
	Epilobium angustifolium	8	1	7	17
	Sanguisorba sitchensis	19.5	13	6.5	16
	Anaphalis margaritacea	19.5	17	2.5	13
	Hypochaeris radicata	19.5	10	9.5	18
Ferns	Polystichum munitum	14	20.5	-6.5	5
	Blechnum spicant	3	15	-12	3
Grasses	spp. (unclassified)	5.5	8.5	-3	8
Sedges	spp. (unclassified)	11	11.5	-.5	10

[a]Formerly named Lactuca muralis.

TABLE 17. A rank usage-availability comparison between species composition in the winter diet and availability on the Greenstone herd winter range

Forage Class	Species	Rank: Usage 1983	Usage 1984	Availability 1983	Availability 1984	Difference 1983	Difference 1984	Relative preference 1983	Relative preference 1984	
Conifers[a]	Tsuga heterophylla	1	2	3	11	-2	-9	5	2	*
	Pseudotsuga menziesii	14	10	5	9	9	1	8	5	
	Thuja plicata	9	7	12	4	-3	3	4	7	
	Pinus sp.	14	12	14	8	0	4	6	8	
Shrubs	Vaccinium sp.	7	11	2	3	5	8	7	10	
	Gaultheria shallon	6	5	1	1	5	4	7	8	
	Mahonia nervosa	14	8	4	2	10	6	9	9	
	Myrica gale	11	14	11	6	0	8	6	10	
	Rubus sp.	10	14	10	13	0	1	6	5	
Forbs	Linnaea borealis[b]	3	3	7	10	-4	-7	3	3	*
Ferns	Blechnum spicant	5	6	13	15	-8	-9	1	2	*
	Polystichum munitum	8	9	8	7	0	8	6	10	
	Pteridium aquilinum	12	14	-	12	-	2	-	6	
Grasses	spp. (unclassified)	2	4	9	14	-7	-10	2	1	*
Sedges	spp. (unclassified)	4	1	6	5	-2	-4	5	4	*

*The top five preferred species during 1983 and 1984.

[a]The conifer class includes litter and all available conifer forage below 2 m.

[b]Linnaea borealis is an evergreen, herb-like shrub (Hitchcock and Cronquist 1973) which was placed in the forb class because of its occurrence in the herb layer (after Walmsley et al. 1980).

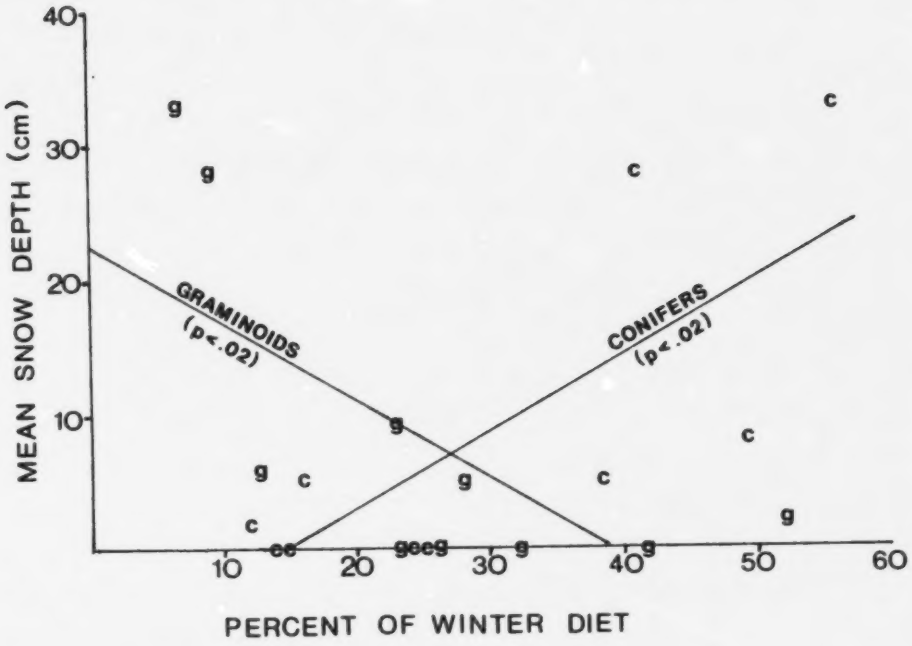

FIGURE 9. Relationships between percent graminoids in diet and snow depth (g), and between percent conifers in diet and snow depth (c).

Multiple regression analyses and Spearman rank correlations indicated no significant relationships between four species variables (tannin content [mg/g], percent availability, percent crude protein, and percent dry matter digestibility) and percent use in the winter diet ($p>.10$) in 1983 and 1984 (Table 18).

4.10 Winter Habitat Use

Use of stand types and ecosystems (Table 1) on the winter range (Figure 10) during 1983 and 1984 was disproportionate to availability. Generally, non-productive forest types (bogs and rock bluffs), deciduous stands, and 20- to 60-year-old second-growth were selected, while 0- to 20-year-old second- growth and 20- to 40-year-old spaced second-growth stands were avoided (Table 19). The use of spaced stands increased when wetter ecosystem associations occurred within the stands. Use of old growth was proportional to its availability, though it should be noted that the low availability of old growth (1%), the small size of individual stands, and the dispersion of these stands in this study area make it difficult to draw conclusions about the importance of old growth.

Use of ecosystem associations was also disproportionate to availability (Table 20). During both winters, the driest ecosystem associations - 1 (Rhacomitrium-lichen) and 2 (Gaultheria) - were avoided, while ecosystem associations 5 (moss-Mahonia) and 11 (Carex-Myrica-Spiraea) were preferred. The high use of ecosystem association 5 occurred in 20- to 60-year-old second-growth stands. The high use of ecosystem association 11 occurred in bogs. Comparison of percent availability and percent use in stand type-ecosystem associations indicates the trend with all elk monitored in both winters to select the associations 1.11 (bogs), 2.7 (deciduous-conifer complex), and 4.5 (20- to 60-year-old forest/moss-Mahonia) (Table 21).

TABLE 18. Plant species variables regressed with percent use in the winter diet for the Greenstone herd, using stepwise forward multiple regression and Spearman rank correlation

Year and plant variables	Partial regression coefficient	Coefficient of determination R^2	Simple correlation coefficient (r)	Spearman rank correlation coefficient (r)
1983				
Tannin content (mg/g)	.06	.003	.05	-.07
Percent availability	-.18	.02	-.09	.45
Percent crude protein[b]	-1.01	.03	-.07	-.09
Percent dry matter Digestibility[c]	-.36	.11	-.23	-.39
1984				
Tannin content (mg/g)	-.24	.006	.08	.04
Percent availability	-.14	.006	.04	.19
Percent crude protein	-2.79	.22	-.42	-.44
Percent dry matter Digestibility	-.26	.26	-.16	-.44

[a]Variables are listed in the order they were entered into the multiple regression.
[b]Percent crude protein values from Janz (1983).
[c]Percent dry matter digestibility from Janz (1983) and Rochelle (1980).

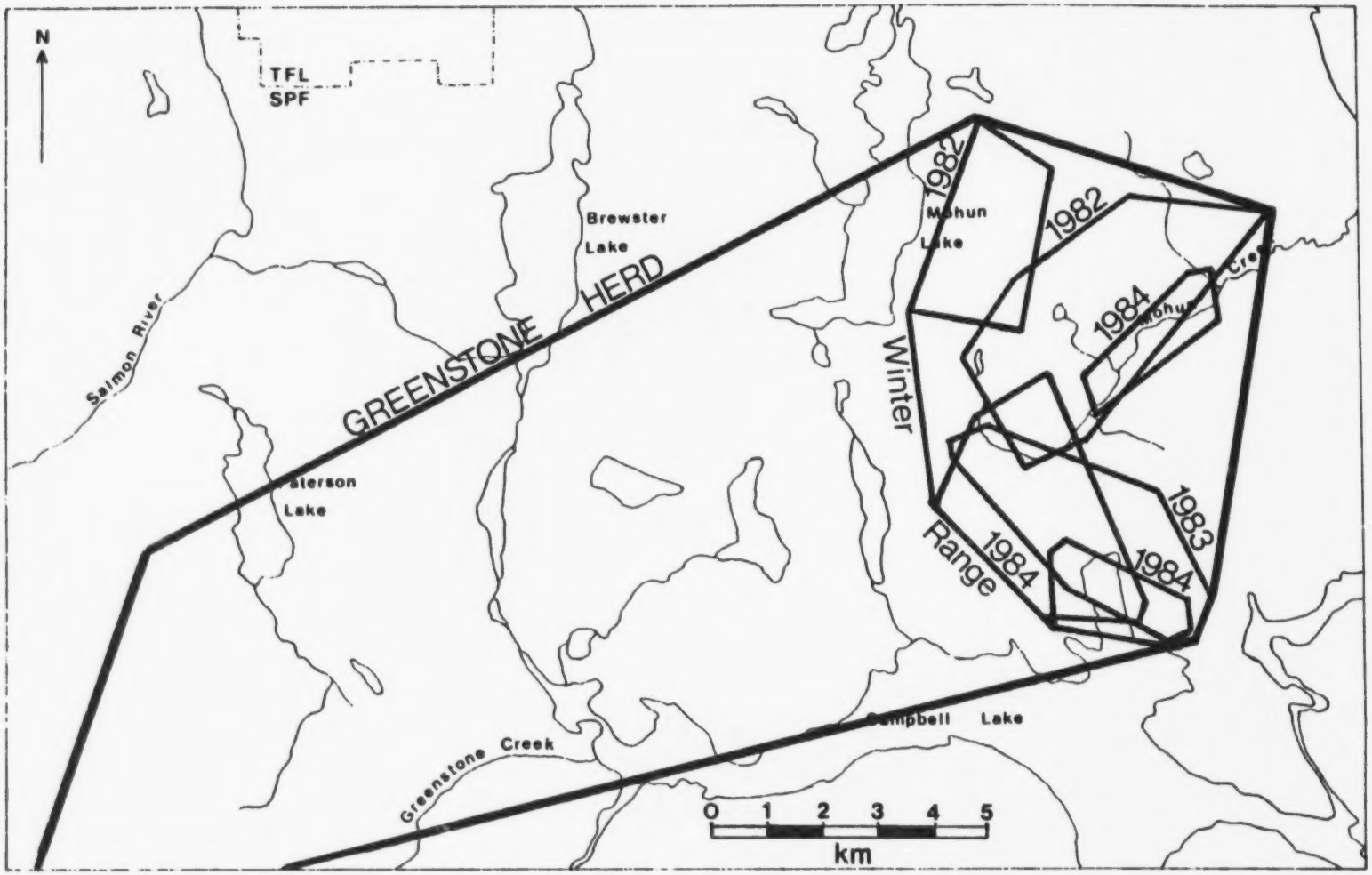

FIGURE 10. Winter ranges of Greenstone herd elk during 1982, 1983, and 1984.

TABLE 19. Percent use-availability and selection of stand types during 1983 and 1984 winters

Stand[a] Type	% availability	Percent use					Selection		
		1983-f.641[b]	1984-f.641[b]	1984-f.590[b]	1984-f.490[b]	Pooled	1983	1984	Pooled
1	7.5	16.0	17.1	2.5	0	12.2	+	0	+
2	3.7	3.7	8.5	7.5	28.3	8.4	0	+	+
3	11.8	4.3	0	2.5	0	2.8	-	-	-
4	63.2	74.9	57.4	82.5	71.7	72.8	+	0	+
5	12.7	0	17.0	5.0	0	3.1	-	-	-
6	1.1	1.1	0	0	0	0.6	0	0	0
n		187.0	47.0	40.0	46.0	320.0			

[a]Stand types:

1 = Non-productive forest-land (bogs and bluffs)
2 = Deciduous-conifer complex
3 = 1- to 20-year-old forest
4 = 21- to 60-year-old forest
5 = 21- to 40-year-old spaced forest
6 = old growth (_ 200 years) forest.

[b]Animal identifiers.

[c]Selection based on Bonferroni-chi-square analyses, using 80% confidence intervals ("+" = preference, "-" = avoidance, "0" = no selection).

TABLE 20. Percent use/availability and selection of ecosystem associations during the 1983 and 1984 winters

Ecosystem[a] association	Percent availability	Percent use					Selection[c]		
		1983-f.641[b]	1984-f.641[b]	1984-f.590[b]	1984-f.490[b]	Pooled	1983	1984	Pooled
1	7.1	1.5	2.1	2.5		1.5	-	-	-
2	40.4	28.7	29.8	15.0	2.1	22.9	-	-	-
5	40.4	50.8	36.2	72.5	58.7	51.2	+	+	+
6	1.1	1.0	4.3			1.2	0	0	0
7	8.6	2.6	17.0	7.5	39.1	10.4	-	+	0
11	2.4	15.4	10.6	2.5		10.4	+	0	+
n		187.0	47.0	40.0	46.0	328.0			

[a] ecosystem associations:
1 = Rhacomitrium - Lichen spp.
2 = Gaultheria
5 = Moss-Mahonia
6 = Blechnum
7 = Polystichum-Achlys
11 = Carex-Myrica-Spiraea

[b] Animal identifiers

[c] Selection based on Bonferroni-chi-square analyses, using 80% confidence intervals ('+' = preference, '-' = avoidance, '0' = no selection).

TABLE 21. Percent availability and use by stand type-ecosystem associations during the 1983 and 1984 winters

Stand type[a] ecosystem association	Percent availability	Percent use				Pooled data
		1983-f.641[b]	1984-f.641[b]	1984-f.590[b]	1984-f.490[b]	
1.1	5.3		2.1			0.3
1.5	0.06					
1.6	0.04					
1.9	0.04					
1.11	2.1	16.0	10.6	2.5		11.3
2.6	0.04	1.1				0.6
2.7	3.7	2.7	8.5	7.5	28.3	7.8
3.1	0.9	1.6		2.5		1.3
3.2	10.8	2.7				1.5
3.5	0.03	0.5				0.3
4.1	0.2					
4.2	23.8	22.3	23.4	10.0	2.2	26.2
4.5	35.1	52.1	34.0	72.5	58.7	45.0
4.6	0.4					
4.7	3.7				10.8	1.5
5.2	7.7		6.4	5.0		1.5
5.5	4.9		2.1			0.3
5.7	0.07		8.5			1.3
6.2	0.6	1.1				0.6
6.5	0.02					
6.6	0.5		4.3			0.6
	3 835 ha	187 loc.[c]	47 loc.	40 loc.	46 loc.	320 loc.

[a] See Table 1.
[b] Animal identifiers.
[c] loc = radio-locations

Home range sizes (from four-day monitoring sessions) showed significant negative relationships with the proportion of bogs ($p<.05$), proportion of bogs and deciduous stands ($p<.10$), and proportion of bogs, bluffs, and deciduous stands ($p<.10$) within the home range (Figure 11). The proportion of deciduous stands and the proportion of bluffs were not significantly related to home range size ($p>.10$). These findings suggest that the suitability and carrying capacity of a mild winter range increases as the proportion of bogs increases. Cursory observations suggest that deciduous stands and bluffs increase in importance as snow depths increase, however, severe winter conditions are required to test this hypothesis.

Linear correlation analysis indicated a significant correlation ($p<.0025$) between a stand type preference index (locations per hectare) and the mean percent cover of sedges within stand types (Table 22). Other habitat variables (canopy closure, percent conifers, percent shrubs, percent forbs, percent ferns, percent grasses, percent Tsuga heterophylla, percent Linnaea borealis, and percent Blechnum spicant) had non-significant correlations with the stand type preference index ($p>.20$). The correlation of sedges with habitat preference can be explained by their occurrence in bogs and wetter habitats.

Spearman rank correlations between the stand type preference index (locations per hectare) and the above habitat variables gave results consistent with those of the linear correlation analysis. Mean percent cover of sedges was the only habitat variable that correlated significantly ($p<.10$) with the preference index (Table 22).

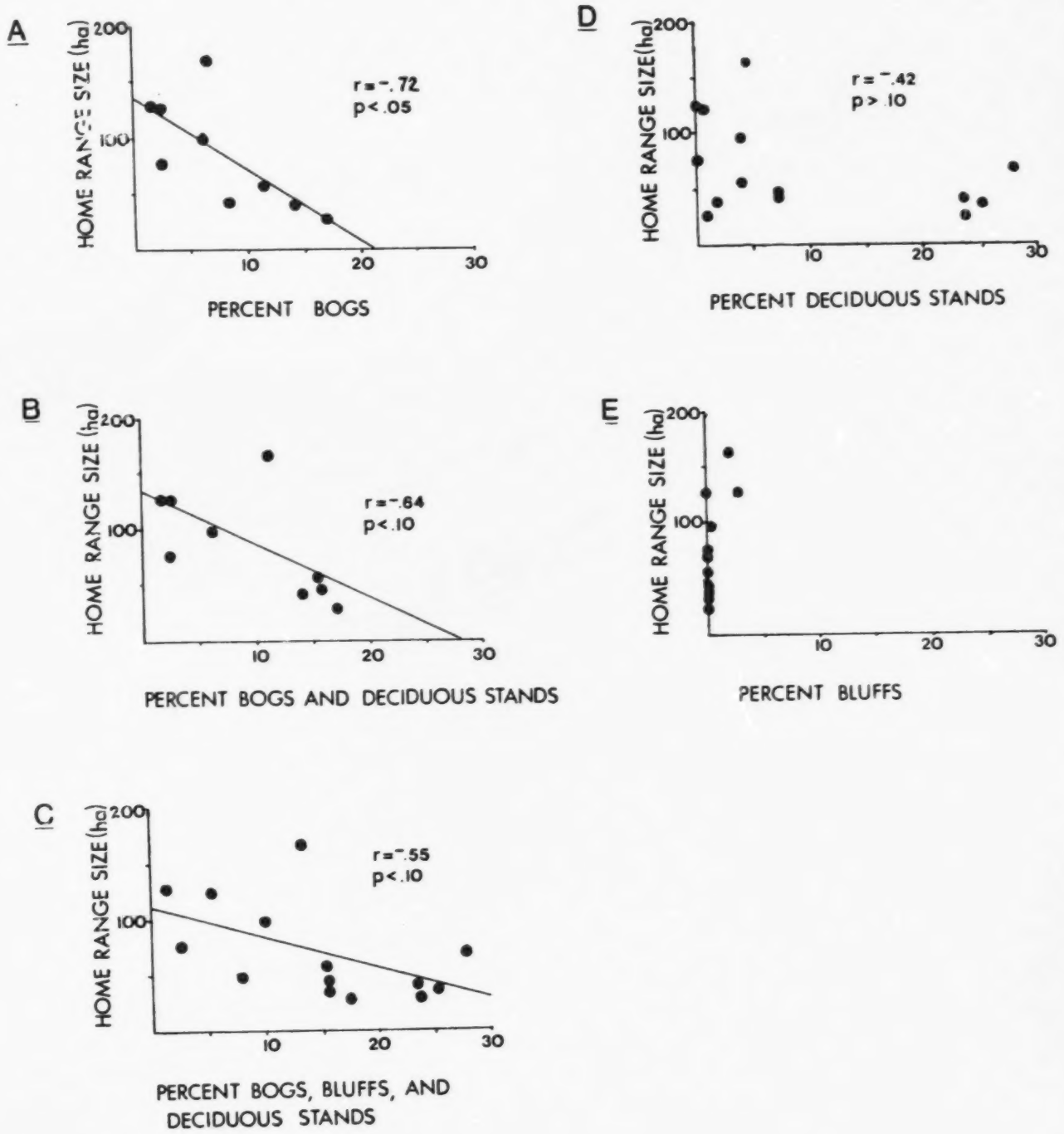

FIGURE 11. Relationships between 4-day home range size and (A) the percent bogs, (B) the percent bogs and deciduous stands, (C) the percent bogs, bluffs, and deciduous stands, (D) the percent deciduous stands, and (E) the percent bluffs within the home range.

TABLE 22. Habitat variables associated with stand type preference during winter as indicated by multiple regression. Regression coefficients for linear regressions and Spearman rank correlations between stand type preference and these habitat variables are also shown.

Habitat variable	Multiple regression		Simple correlation coefficient	Spearman rank coefficient
	Partial regression coefficient	R^2		
Sedges	.0034	.833	.913[a]	.673[b]
Grasses	-.0148	.868	-.082	-.101
Canopy closure	-.0019	.890	-.364	.042
Tsuga heterophylla	-.0752	.952[c]	-.407	-.208

[a] $p<.0025$
[b] $p<.025$
[c] $p<.10$

Spearman rank correlations between canopy closure and temperature, and canopy closure and wind speed were non-significant ($p>.20$). No relationships between weather and habitat use were expected due to the mild winter conditions experienced during the study period.

A multiple regression model incorporating four habitat variables (mean percent cover of sedges, mean percent cover of grasses, canopy closure, and mean percent cover [below 2 m] of Tsuga heterophylla) was significant ($p<.025$) and explained 95% of the variation in stand type preference (Table 22).

Distance to forage area (defined as an opening) on the winter range was evaluated from radio-locations (n=132) in forested stand types (Figure 12). The mean distance from cover to forage areas was 143 m. Eighty percent of locations occurred within 200 m of a forage area. Approximately 50% of the area of the Greenstone winter range used during 1983 and 1984 was greater than 200 m from a forage area.

4.11 Activity

Winter daily activity patterns were very similar in 1983 and 1984 (Figure 13). Since both winters were mild, large variations in activity patterns between years was not expected. The most striking feature was the high level of activity near sunrise and sunset.

Mean active:inactive ratios varied significantly between 1983 and 1984 ($p<.10$) (Table 23). This difference is attributable to session three in 1983 in which percent time active (57.9%) was approximately 10% higher than during any other session. During this session the elk were near the road systems from which they were being located, and disturbance may have been a factor in the higher percent activity observed. Mean temperature during each session was not significantly related to percent activity ($p>.10$).

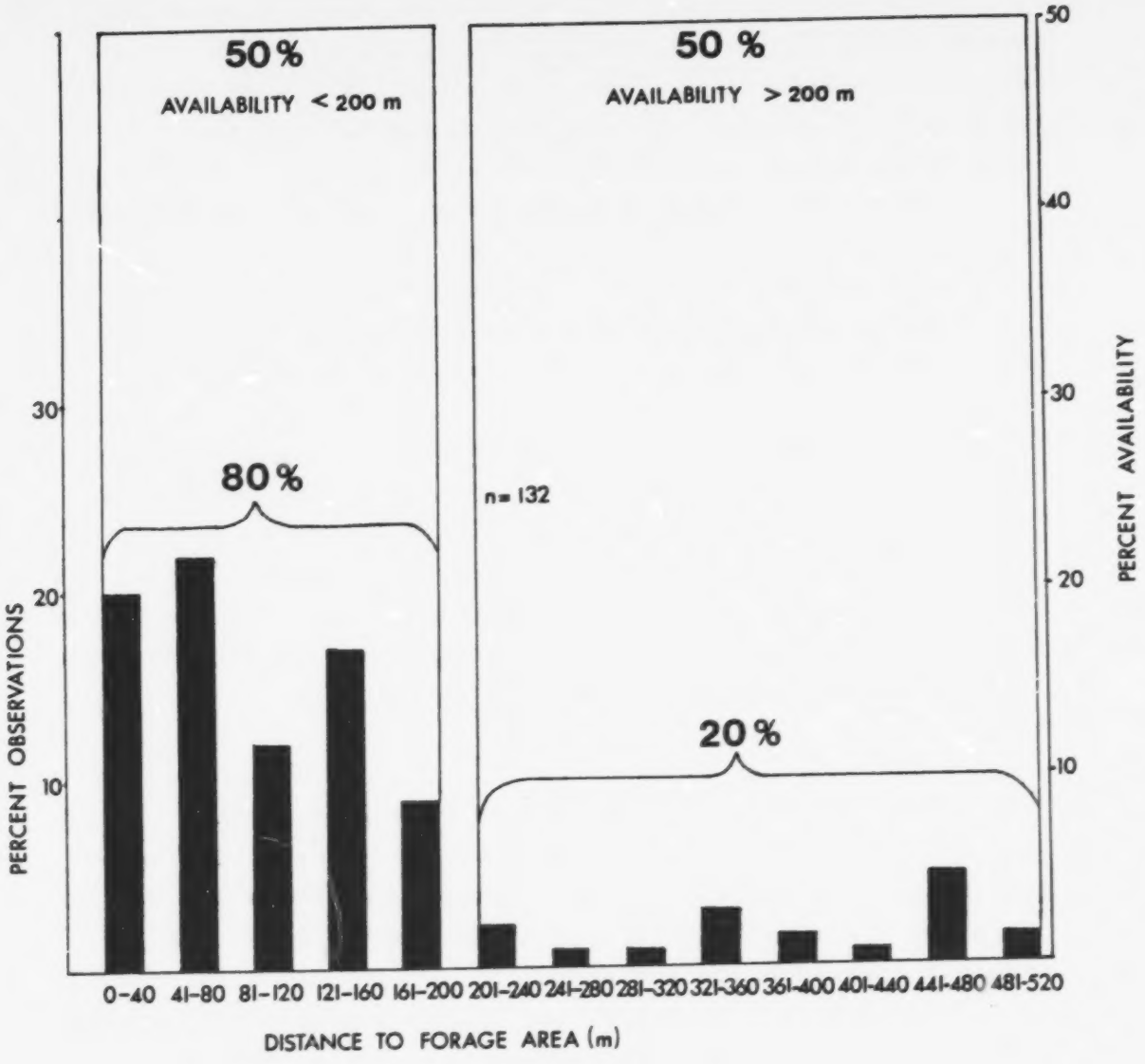

FIGURE 12. Frequency histogram of the distance to forage area (openings) of radio-locations in forested stands, collected from the Greenstone herd in January-February 1983. Availability of forested stands < 200 m and > 200 m from openings on the southern portion of the Greenstone winter range is also shown.

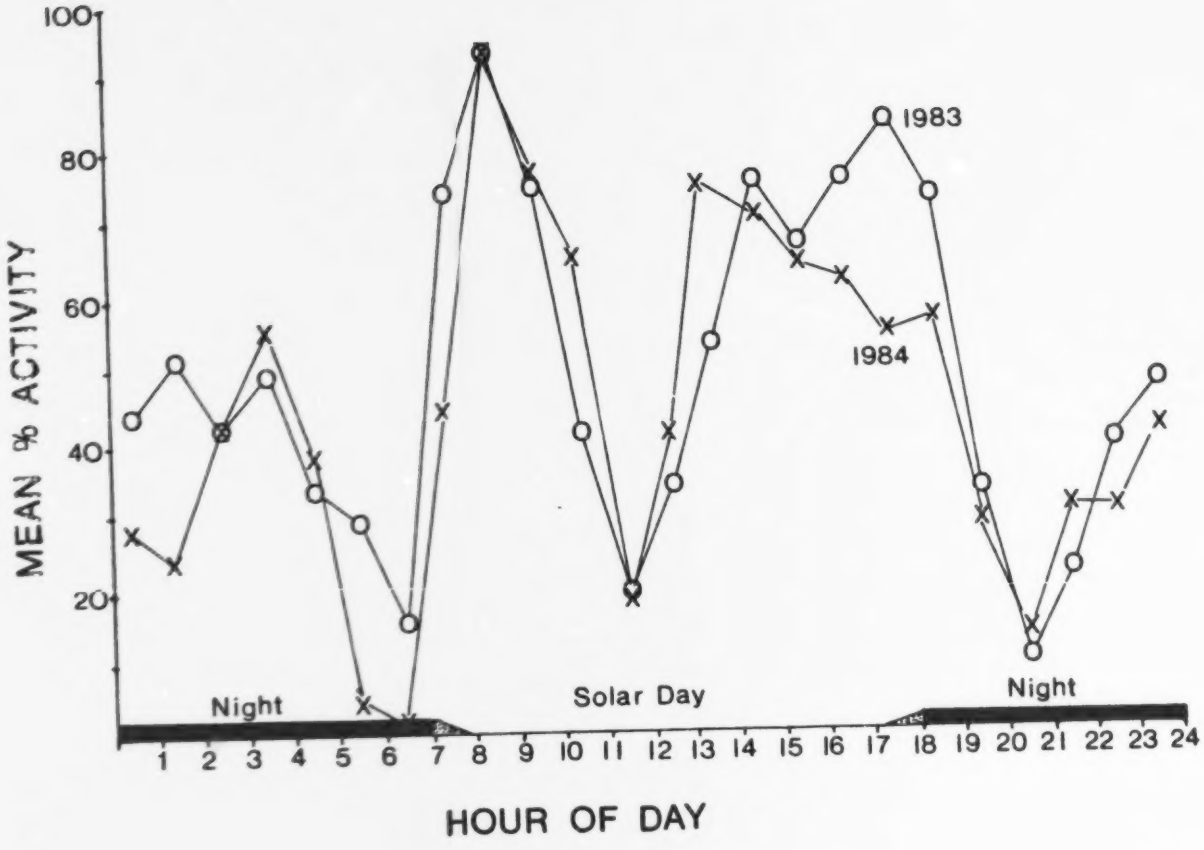

FIGURE 13. Mean percent activity by hour for one radio-collared elk cow in the Greenstone herd during January and February 1983 and 1984.

TABLE 23. Percent of time active and inactive, mean length of activity periods, and mean temperature during each monitoring session in 1983 and 1984

Year	Session	Percent active	Percent inactive	Active: inactive ratio	Mean length of activity periods (hr)	Mean temp. (°C)
1983	Jan. 25-28	57.9	42.1	1.38	1.7	4.7
	Feb. 10-13	44.1	55.9	0.79	1.1	3.8
	Feb. 19-22	47.0	53.0	0.89	1.2	4.7
1983	Mean	49.7	50.3	1.02	1.3	4.4
1984	Jan. 10-13	42.9	57.1	0.75	0.8	--
	Jan. 23-26	48.2	51.8	0.93	1.2	2.8
	Jan. 31-Feb. 3	43.3	56.7	0.76	1.0	1.9
	Feb. 12-15	48.0	52.0	0.92	1.3	2.6
	Feb. 19-22	44.6	55.5	0.80	1.6	3.4
1984	Mean	45.4	54.6	0.83	1.2	2.7

Sample sizes for percent active and inactive locations by stand type are too low for statistical comparison (Table 24). However, a trend of higher percent activity in stand type 1 (principally bogs during 1983 and 1984) is apparent. Spearman rank correlations between percent canopy closure of the stand type in which each location occurred and percent activity during the location hour were non-significant ($p>.20$).

Estimates of daily winter energy requirements were made based on the mean percent time active and inactive, and estimates of energy expenditure for elk in these activities (Gates and Hudson 1978; Parker 1983) (Table 25). Gates and Hudson used 10-month-old calves in estimating energy expenditure whereas Parker used calves less than four months of age. Energy requirements per day were estimated to range from 8171 to 15 195 kcal for a 250-kg elk.

Spearman rank correlations between temperature at the time of each location and percent activity during the location hour were also non-significant ($p>.20$). These results were expected due to the mild winter conditions.

4.12 Calving Habitat Use

Calving sites (n=9) were found to occur on winter range, transitional range, and summer range, although the majority of calving activity occurred on summer range. Seven of nine calving sites occurred in second-growth (Table 26). Generally, calving sites were located on flat or gently sloping ground.

TABLE 24. Percent active and inactive locations by stand type during the 1983 and 1984 winters

Stand[a] type	Total locations with activity	Percent active (n)	Percent inactive (n)
1	15	87 (13)	13 (2)
2	8	50 (4)	50 (4)
3	7	57 (4)	43 (3)
4	95	46 (44)	54 (51)
5	2	(1)	(1)
6	9	56 (5)	44 (4)

[a]Stand types:
1 = Non-productive forest-lands (bogs and bluffs)
2 = Deciduous-conifer complex
3 = 1- to 20-year-old forest
4 = 21- to 60-year-old forest
5 = 21- to 40-year-old spaced forest
6 = Old growth ($\geq$ 200 years) forest

TABLE 25. Time-activity budget for a 250 kg elk during winter, based on energy expenditure values from Parker (1983) and Gates and Hudson (1978)

Author	Activity	Energy expenditure		Percent time	Energy requirements for 250-kg elk	
		kcal/kg/min	kcal/kg/day		Activity kcal/day	Daily total kcal/day
Parker	lying	0.0289				
	standing	0.0362				
	walking[a]	0.0700				
	inactive[b]	0.0326	46.9	53.0	6210	15 195
	active[c]	0.0531	76.5	47.0	8985	
Gates and Hudson	lying	0.0172				
	standing	0.0217				
	walking[d]	0.0308				
	inactive[b]	0.0195	28.1	53.0	3721	8171
	active[c]	0.0263	37.9	47.0	4450	

[a] Horizontal walking at 2 km/hr (30 m/min).
[b] An average of lying and standing energy costs.
[c] An average of walking and standing energy costs.
[d] Horizontal walking at 4 km/hr (67 m/min).

TABLE 26. Calving site attributes for sites examined during 1983 and 1984

Site attribute	1983			1984[a]					
	41	252	1038	41	262	391	540	1037	1280
Elevation (m)	700	500	650	250	<50	600	400	600	250
Stand type	3	1	3	4/1	2	3	3/1	6/1	4/1
Slope (degrees)	0	0	6	0	0				
Overstory height (m)	<2	0	<2	36-65					
Overstory age (yr)	7	n/a	3	21-40	-	18	12-16	250+	38

[a]All data for 1984 has not been collected.

During the calving period, all observed cows were solitary, and remained solitary for a 10- to 20-day period. Calving sites were generally less than 1 ha in size. Security appears to be an important criterion for site selection. When elk were disturbed at (suspected) calving sites prior to calving, they were observed to make long movements (several kilometres) over the subsequent 24-hour period.

4.13 Summer Habitat Use

During summer, elk monitored in the Grilse migratory herd used stand type 6 (mature timber) 38% of the time, stand type 3 (0- to 20-year-old second-growth) 34% of the time, stand type 1 (non-productive forest land) 17% of the time, and stand type 2 (deciduous-conifer complex) 11% of the time (Table 27). On a use-availability basis, only stand types 1 and 2 were used proportionately greater than their availability.

From sightings of elk on the summer range, distance to forest edge in 0 to 10-year-old second-growth stands was evaluated (Figure 14). Greater than 50% of sightings (n=48) occurred within 40 m of a forest edge. Ninety-five percent of sightings occurred within 200 m of a forest edge. The maximum distance to forest edge observed was 300 m. Opening sizes were variable. However, on the Grilse summer range approximately 40% of the area in openings is greater than 200 m from a forest edge; availability on the Greenstone summer range is similar.

TABLE 27. Radio-locations by stand type for two intensive monitoring sessions conducted on the Grilse herd summer range

Stand type	June 28-July 2, 1982		May 30-June 9, 1983		Total	
	Area (%)	Locations (%)	Area (%)	Locations (%)	Area (%)	Locations (%)
1 - bog	6.9	17.8	5.3	16.3	4.5	17.0
2 - deciduous	4.3	17.8	0.9	4.6	2.8	11.4
3 - 0- to 20-year second growth	53.7	48.9	18.2	18.6	40.8	34.1
6 - mature timber	35.1	15.5	75.5	60.5	51.9	37.5
Totals (hectares, locations)	311.0	45.0	235.0	43.0	477.0	88.0

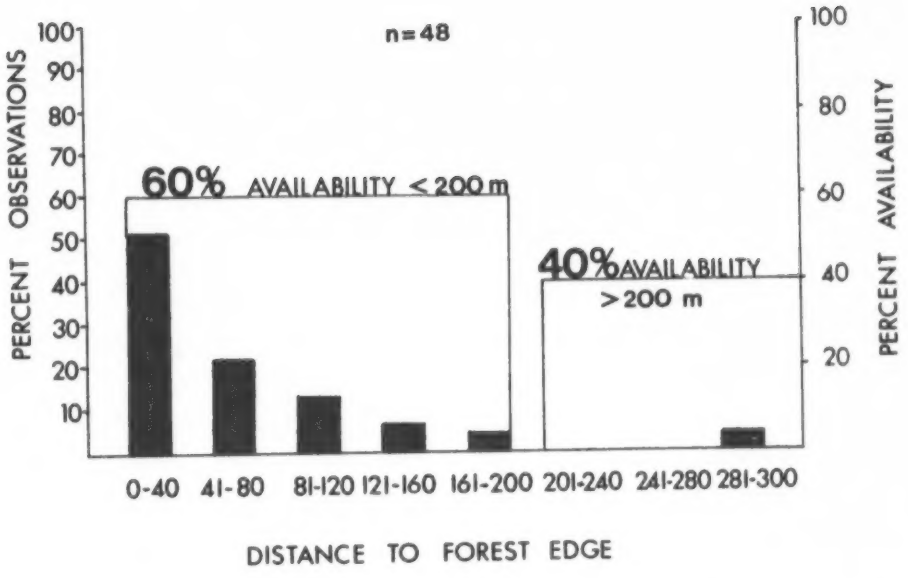

FIGURE 14. Frequency histogram of the distance to forest edge of elk sighted in 0- to 10-year-old clearcuts, collected from the Grilse and Greenstone herds during summer and fall 1981 and 1982. Availability of openings < 200 m and > 200 m from a forest edge on the Grilse summer range is also shown.

4.14 Use of Spaced Stands

Use of spaced stands during the course of 3 years has been minimal. During winter, spaced stands were significantly avoided ($p<.20$) (Table 19).

Winter home ranges generally fell between large areas of spacing. The avoidance of spaced stands is probably related to substantial debris depths (0.5 m-2.0 m), which are energetically costly in terms of locomotion. Based on information from Parker (1983), it is estimated that energy expenditure for elk increases 14-20 times with 50 obstacles/100 m and depths of 1 m.

5.0 CONCLUSIONS

Research objectives (Section 1.2) have not yet been completely satisfied. The study has provided substantial ecological information on elk habitat use, food habits, migration, condition, and population status in immature forests considered representative of Vancouver Island. Additional information collected on seasonal use of stand and ecosystem types, seasonal use of forage species, use of back-log spaced stands, and calving habitat requirements has satisfied some of the specific research objectives. Other objectives, including work on security cover requirements, optimum forage-cover ratios, the influence of winter severity on population growth and animal condition, and the impact of predation on elk populations, have only been partially satisfied. Research objectives concerning use of forest stand and ecosystem types during severe winter conditions, the requirements for thermal cover, and the impact of silvicultural activities on population growth have not been met, primarily due to the mild winter conditions so far experienced.

Management implications from this research will be discussed in detail in the final project report. Briefly, the major management implications will include the following:

1. The importance of forage production on winter ranges, particularly in natural openings. These natural openings (bogs, bluffs) will require protection, including adequate security cover adjacent to or around them. Dense, immature forests, which include few natural openings, may require low density spacing programs to enhance forage production.

2. The importance of protecting deciduous stands for elk use, particularly along low elevation water courses.

3. The importance of debris treatment (trails, bucking, or removal) in back-log spaced stands to afford elk access and improve forage production.

4. The importance of protecting (through visual screens) bogs-meadow complexes on all seasonal ranges.

5. For optimum elk use, logging block width should probably not exceed 200 m.

6. The importance of minimizing human disturbance on or near calving grounds from May through June.

Further research is required to study elk habitat use during a winter with heavy snowfall and prolonged accumulations. Information on elk use and survival in immature forests under heavy snow conditions will prove to be critical in the development of a complete elk management model.

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